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U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
CHARLES F. MARVIN, Chief

# MONTHLY WEATHER REVIEW

VOLUME 46, No. 2

## FEBRUARY, 1918

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1918

# FEBRUARY, 1918.

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### NOTICE TO CONTRIBUTORS.

Contributions intended for publication in any given issue of the MONTHLY WEATHER REVIEW (e. g., January) should be in the hands of the editor before the end of the next following month (e. g., February), if no illustrations are required. When the paper is illustrated, the manuscript and the copy for illustrations must be submitted much earlier, in order to permit copy being prepared for the engraver by the end of the month.

REPRINTS are made up without covers in the original size and pagination of the REVIEW. They will not be furnished unless specifically REQUESTED WHEN THE MANUSCRIPT IS SUBMITTED.

# MONTHLY WEATHER REVIEW

CLEVELAND ABBE, jr., Editor.

VOL. 46, No. 2.
W. B. No. 640.

FEBRUARY, 1918.

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## INTRODUCTION.

As explained in this Introduction during 1914, the MONTHLY WEATHER REVIEW now takes the place of the Bulletin of the Mount Weather Observatory and of the voluminous publication of the climatological service of the Weather Bureau. The MONTHLY WEATHER REVIEW contains contributions from the research staff of the Weather Bureau and also special contributions of a general character in any branch of meteorology and climatology.

SUPPLEMENTS to the MONTHLY WEATHER REVIEW are published from time to time.

The climatological service of the Weather Bureau is maintained in all its essential features, but its publications, so far as they relate to purely local conditions, are incorporated in the monthly reports "Climatological Data" for the respective States, Territories, and colonies.

Since August, 1915, the material for the MONTHLY WEATHER REVIEW has been prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology.*—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology.*—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere.*

SECTION 4.—*Rivers and floods.*

SECTION 5.—*Seismology.*—Results of observations by Weather Bureau observers and others as reported to the Washington office.

SECTION 6.—*Bibliography.*—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 7.—*Weather of the month.*—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto; Meteorological Summary and chart No. 9 of the North Atlantic Ocean for this month in 1917. Owing to the fact that ocean meteorological data are frequently not available for a considerable time after the close of the month to which they relate, the chart and text matter in connection therewith appear one year late.

In general, appropriate officials prepare the seven sections above enumerated; but *all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.*

The voluminous tables of data and text relative to local climatological conditions, that during recent years were prepared by the 12 respective "district editors," are omitted from the MONTHLY WEATHER REVIEW, but are collected and published by States at selected section centers. (See cover, p. 3.)

The data needed in Section 7 can only be collected and prepared several weeks after the close of the month designated on the title-page; hence the REVIEW as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are specially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belén College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

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The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but such publication is not to be construed as official approval of the views expressed.

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## CORRIGENDA.

REVIEW, January, 1918:

Page 47, Condensed Climatological Summary, for the State of Washington, *substitute* the following values:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36.6° | +5.9° | 3 stations..... | 70° | 1 | Anatone..... | −15° | 31 | 4.88 | +0.19 | Cedar Lake..... | 21.85 | Wenatchee..... | 0.30 |

Page 47, same table, footnote, "Mare Island" should *read* "League Island."

Page 54, Table III, for Barkerville lowest temperature *read* "−22°."

52303—18——1

# SECTION I—AEROLOGY.

## SOLAR AND SKY RADIATION MEASUREMENTS DURING FEBRUARY, 1918.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., Mar. 30, 1918.]

For a description of instrumental exposures and an account of the methods of obtaining and reducing the measurements the reader is referred to the Review for January, 1918, **46**:2.

The monthly means and departures from normal values in Table 1 show that direct solar radiation intensities averaged slightly above normal at Madison, Wis., slightly below at Lincoln, Nebr., and Santa Fe, N. Mex., and decidedly below at Washington, D. C.

Table 3 shows an excess of radiation of about 4 per cent and 3 per cent, respectively, at Washington and Madison, as compared with the normal radiation for these stations for February, and a deficiency of about 6 per cent for Lincoln.

In Table 4 are given the results obtained by extrapolating to zero air mass series of readings by the Marvin pyrheliometer that indicated steady atmospheric conditions during a half-day period.

Skylight polarization measurements obtained at Washington on 5 days during the second half of the month give a mean 47 per cent, with a maximum of 65 per cent on the 26th. These values are considerably below the average for Washington in February. No polarization measurements were obtained at Madison on account of the continuous presence of snow on the ground.

TABLE 1.—*Solar radiation intensities during February, 1918.*

[Gram-calories per minute per square centimeter of normal surface.]

**Washington, D. C.**

| Date | Sun's zenith distance. 0.0° | 48.3° | 60.0° | 66.5° | 70.7° | 73.6° | 75.7° | 77.4° | 78.7° | 79.8° |
|---|---|---|---|---|---|---|---|---|---|---|
| | Air mass. 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 |
| 1918. A. M. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. |
| Feb. 4 | ..... | ..... | 1.15 | 1.03 | 0.91 | ..... | 0.72 | ..... | ..... | ..... |
| 11 | ..... | 1.17 | 1.01 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 14 | ..... | ..... | 0.86 | ..... | 0.61 | 0.56 | 0.52 | ..... | ..... | ..... |
| 15 | ..... | 1.32 | 1.18 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 18 | ..... | 1.26 | 1.01 | 0.95 | 0.88 | 0.83 | ..... | 0.73 | ..... | ..... |
| 21 | ..... | 1.28 | 1.10 | 0.95 | ..... | ..... | ..... | ..... | ..... | ..... |
| 23 | ..... | 1.42 | 1.16 | 1.04 | 0.96 | ..... | 0.82 | 0.74 | 0.66 | ..... |
| 25 | ..... | ..... | ..... | 0.79 | ..... | ..... | 0.63 | ..... | ..... | ..... |
| 26 | ..... | 1.49 | 1.37 | 1.28 | 1.22 | 1.16 | ..... | ..... | ..... | ..... |
| 27 | ..... | 1.37 | ..... | 1.24 | 1.01 | ..... | 0.79 | 0.70 | ..... | ..... |
| Monthly means | ..... | 1.33 | 1.10 | 1.04 | 0.93 | 0.85 | 0.70 | 0.72 | (0.66) | ..... |
| Departure from 10-year normal | ..... | −0.06 | −0.12 | −0.08 | −0.11 | −0.11 | −0.16 | −0.14 | −0.12 | ..... |
| P. M. | | | | | | | | | | |
| Feb. 11 | ..... | ..... | 1.01 | 0.89 | 0.80 | 0.73 | 0.66 | 0.60 | ..... | ..... |
| 15 | ..... | ..... | 0.72 | 0.70 | 0.58 | 0.48 | ..... | ..... | ..... | ..... |
| 18 | ..... | ..... | ..... | 1.12 | 1.08 | 0.96 | 0.84 | 0.73 | 0.68 | 0.64 |
| 21 | ..... | ..... | 1.13 | 1.03 | 0.84 | 0.73 | 0.59 | 0.54 | 0.50 | 0.47 |
| 23 | ..... | ..... | 1.22 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 26 | ..... | ..... | 1.31 | 1.20 | 1.11 | 1.04 | 0.98 | 0.91 | 0.83 | 0.77 |
| Monthly means | ..... | ..... | 1.08 | 0.99 | 0.88 | 0.79 | 0.77 | 0.70 | 0.67 | 0.63 |
| Departure from 10-year normal | ..... | ..... | −0.14 | −0.12 | −0.13 | −0.11 | −0.08 | −0.10 | −0.08 | −0.09 |

TABLE 1.—*Solar radiation intensities during February, 1918*—Contd.

**Madison, Wis.**

| Date | Sun's zenith distance. 0.0° | 48.3° | 60.0° | 66.5° | 70.7° | 73.6° | 75.7° | 77.4° | 78.7° | 79.8° |
|---|---|---|---|---|---|---|---|---|---|---|
| | Air mass. 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 |
| 1918. A. M. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. |
| Feb. 15 | ..... | ..... | 1.52 | 1.37 | ..... | ..... | ..... | ..... | ..... | ..... |
| 22 | ..... | 1.55 | 1.43 | 1.31 | 1.21 | 1.09 | 1.03 | 0.97 | ..... | ..... |
| 23 | ..... | ..... | ..... | ..... | 1.22 | 1.15 | 1.09 | 1.00 | 0.98 | ..... |
| 26 | ..... | ..... | ..... | ..... | 1.30 | ..... | 1.16 | 0.95 | ..... | ..... |
| Monthly means | ..... | (1.55) | (1.48) | (1.34) | 1.24 | (1.12) | 1.09 | 0.97 | (0.98) | ..... |
| Departure from 8-year normal | ..... | +0.03 | +0.10 | +0.03 | ±0.00 | −0.08 | −0.06 | −0.05 | +0.06 | ..... |
| P. M. | | | | | | | | | | |
| Feb. 6 | ..... | ..... | ..... | 1.17 | 1.04 | 0.84 | ..... | ..... | ..... | ..... |
| 12 | ..... | ..... | ..... | 1.24 | 1.20 | 1.11 | ..... | ..... | ..... | ..... |
| 15 | ..... | ..... | 1.46 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Monthly means | ..... | ..... | (1.46) | (1.20) | (1.12) | (0.98) | ..... | ..... | ..... | ..... |
| Departure from 8-year normal | ..... | ..... | +0.06 | −0.12 | −0.10 | −0.16 | ..... | ..... | ..... | ..... |

**Lincoln, Nebr.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| A. M. | | | | | | | | | | |
| Feb. 3 | ..... | ..... | 1.46 | 1.39 | ..... | ..... | ..... | ..... | ..... | ..... |
| 6 | ..... | ..... | 1.42 | 1.34 | 1.26 | 1.21 | 1.15 | 1.08 | 1.03 | 0.97 |
| 20 | ..... | ..... | ..... | 1.34 | ..... | 1.13 | ..... | ..... | ..... | ..... |
| 23 | ..... | ..... | 1.28 | 1.18 | 1.09 | 1.06 | ..... | ..... | ..... | ..... |
| Monthly means | ..... | ..... | 1.39 | 1.31 | (1.18) | 1.13 | (1.15) | (1.08) | (1.03) | (0.97) |
| Departure from 3-year normal | ..... | ..... | −0.04 | −0.02 | −0.07 | −0.01 | +0.07 | +0.06 | −0.01 | +0.02 |
| P. M. | | | | | | | | | | |
| Feb. 3 | ..... | ..... | ..... | 1.29 | ..... | ..... | ..... | ..... | ..... | ..... |
| 16 | ..... | ..... | 1.36 | 1.30 | 1.19 | 1.12 | 1.05 | 1.00 | ..... | ..... |
| 22 | ..... | ..... | ..... | 1.22 | ..... | ..... | ..... | ..... | ..... | ..... |
| 23 | ..... | ..... | 1.33 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Monthly means | ..... | ..... | (1.34) | 1.27 | (1.19) | (1.12) | (1.05) | (1.00) | ..... | ..... |
| Departure from 3-year normal | ..... | ..... | −0.06 | −0.05 | −0.08 | −0.06 | −0.04 | −0.09 | ..... | ..... |

**Santa Fe, N. Mex.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| A. M. | | | | | | | | | | |
| Feb. 1 | ..... | 1.48 | 1.39 | 1.34 | ..... | ..... | ..... | ..... | ..... | ..... |
| 9 | ..... | 1.51 | 1.41 | 1.32 | 1.24 | ..... | ..... | ..... | ..... | ..... |
| 13 | ..... | ..... | ..... | ..... | ..... | 1.15 | 1.10 | 1.02 | ..... | ..... |
| 14 | ..... | ..... | 1.40 | 1.33 | 1.25 | 1.20 | 1.17 | 1.13 | ..... | ..... |
| 15 | ..... | ..... | ..... | 1.29 | ..... | ..... | ..... | ..... | ..... | ..... |
| 23 | ..... | ..... | ..... | ..... | 1.25 | ..... | ..... | ..... | ..... | ..... |
| Monthly means | ..... | (1.50) | 1.40 | 1.32 | 1.25 | (1.18) | (1.14) | (1.08) | ..... | ..... |
| Departure from 6-year normal | ..... | −0.07 | −0.06 | −0.05 | −0.05 | −0.09 | −0.08 | ±0.00 | ..... | ..... |
| P. M. | | | | | | | | | | |
| Feb. 1 | ..... | ..... | 1.47 | 1.39 | 1.30 | 1.22 | ..... | ..... | ..... | ..... |
| 9 | ..... | ..... | 1.40 | 1.32 | 1.22 | 1.13 | 1.04 | ..... | ..... | ..... |
| 12 | ..... | ..... | 1.32 | 1.27 | ..... | ..... | ..... | ..... | ..... | ..... |
| 14 | ..... | ..... | 1.31 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 16 | ..... | ..... | ..... | 1.30 | 1.24 | 1.17 | ..... | ..... | ..... | ..... |
| 19 | ..... | ..... | ..... | 1.40 | 1.33 | 1.25 | ..... | ..... | ..... | ..... |
| Monthly means | ..... | ..... | 1.38 | 1.34 | 1.27 | 1.19 | (1.04) | ..... | ..... | ..... |
| Departure from 2-year normal | ..... | ..... | −0.01 | −0.01 | −0.02 | ..... | −0.11 | ..... | ..... | ..... |

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

| Washington, D. C. | | | Madison, Wis. | | | Lincoln, Nebr. | | | Santa Fe, N. Mex. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dates. | A. M. | P. M. | Dates. | A. M. | P. M. | Dates. | A. M. | P. M. | Dates. | A. M. | P. M. |
| 1918. | *mm.* | *mm.* | 1918. | *mm.* | *mm.* | 1918. | *mm.* | *mm.* | 1918. | *mm.* | *mm.* |
| Feb. 4 | 1.12 | 0.64 | Feb. 6 | 2.16 | 2.74 | Feb. 3 | 1.32 | 1.52 | Feb. 1 | 1.32 | 1.96 |
| 11 | 4.17 | 4.57 | 12 | 4.17 | 3.45 | 6 | 3.99 | 5.16 | 9 | 2.16 | 2.06 |
| 14 | 3.81 | 7.29 | 15 | 0.97 | 1.07 | 16 | 0.86 | 1.24 | 12 | 2.74 | 2.74 |
| 15 | 7.57 | 3.81 | 22 | 0.97 | 1.88 | 20 | 0.48 | 0.74 | 13 | 2.74 | 2.16 |
| 18 | 1.78 | 2.87 | 23 | 2.62 | 4.75 | 22 | 1.68 | 3.00 | 14 | 2.26 | 2.06 |
| 21 | 1.24 | 1.19 | 26 | 1.68 | 2.87 | 23 | 3.15 | 5.79 | 15 | 2.74 | 2.06 |
| 23 | 1.88 | 2.87 | ..... | ..... | ..... | ..... | ..... | ..... | 16 | 1.96 | 2.06 |
| 25 | 6.02 | 7.57 | ..... | ..... | ..... | ..... | ..... | ..... | 19 | 2.16 | 1.52 |
| 26 | 2.36 | 2.74 | ..... | ..... | ..... | ..... | ..... | ..... | 23 | 4.75 | 3.81 |
| 27 | 3.63 | 4.17 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |

TABLE 3.—*Daily totals and departures of solar and sky radiation during February, 1918.*

[Gram-calories per square centimeter of horizontal surface.]

| Day of month. | Daily totals. | | | Departures from normal. | | | Excess or deficiency since first of month. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Washington. | Madison. | Lincoln. | Washington. | Madison. | Lincoln. | Washington. | Madison. | Lincoln. |
| 1918. | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* |
| Feb. 1 | 122 | 317 | 358 | − 84 | 112 | 95 | −84 | 112 | 95 |
| 2 | 156 | 257 | 306 | − 52 | 49 | 40 | −136 | 161 | 135 |
| 3 | 98 | 315 | 337 | −113 | 105 | 68 | −249 | 266 | 203 |
| 4 | 320 | 338 | 306 | 107 | 125 | 34 | −142 | 391 | 237 |
| 5 | 347 | 137 | 182 | 132 | − 79 | − 93 | − 10 | 312 | 144 |
| 6 | 240 | 297 | 320 | 22 | 78 | 42 | 12 | 390 | 186 |
| 7 | 281 | 176 | 272 | 59 | − 47 | − 10 | 71 | 343 | 176 |
| 8 | 252 | 30 | 34 | 27 | −196 | −251 | 98 | 147 | −75 |
| 9 | 63 | 307 | 376 | −165 | 78 | 87 | − 67 | 225 | 12 |
| 10 | 264 | 274 | 386 | 33 | 41 | 94 | − 34 | 266 | 106 |
| 11 | 313 | 269 | 196 | 79 | 33 | −100 | 45 | 299 | 6 |
| 12 | 226 | 284 | 286 | − 12 | 45 | − 13 | 33 | 344 | −7 |
| 13 | 275 | 257 | 216 | 34 | 14 | − 87 | 67 | 358 | − 94 |
| 14 | 205 | 113 | 147 | − 39 | −133 | −159 | 28 | 225 | −253 |
| 15 | 334 | 359 | 75 | 87 | 110 | −234 | 115 | 335 | −487 |
| 16 | 87 | 271 | 403 | −164 | 18 | 91 | − 49 | 353 | −396 |
| 17 | 369 | 363 | 389 | 115 | 107 | 74 | 66 | 460 | −322 |
| 18 | 371 | 167 | 271 | 114 | − 92 | − 47 | 180 | 368 | −369 |
| 19 | 67 | 32 | 226 | −193 | −231 | − 94 | − 13 | 137 | −463 |
| 20 | 282 | 393 | 437 | 18 | 127 | 114 | 5 | 264 | −349 |
| Decade departure | | | | | | | + 39 | − 2 | −455 |
| 21 | 399 | 267 | 383 | 132 | − 2 | 57 | 137 | 262 | −292 |
| 22 | 129 | 388 | 375 | −141 | 115 | 46 | − 4 | 377 | −246 |
| 23 | 394 | 343 | 363 | 120 | 67 | 31 | 116 | 444 | −215 |
| 24 | 233 | 352 | 294 | − 44 | 73 | − 41 | 72 | 517 | −256 |
| 25 | 184 | 43 | 287 | − 96 | −239 | − 51 | − 24 | 278 | −307 |
| 26 | 448 | 321 | 330 | 164 | 35 | − 11 | 140 | 313 | −318 |
| 27 | 406 | 311 | 90 | 118 | 21 | −254 | 258 | 334 | −572 |
| 28 | 333 | 164 | 368 | 41 | −129 | 21 | 299 | 205 | −551 |
| Decade departure | | | | | | | +294 | − 59 | −202 |
| Excess or deficiency since first of year: cal. | | | | | | | +137 | +869 | −755 |
| Excess or deficiency since first of year: Per cent | | | | | | | +1.1 | +7.1 | −5.0 |

TABLE 4.—*Solar radiation intensities for zenithal sun and approximate values of the solar constant.*

| Station. | Date. | Radiation intensity. | | Solar constant. |
|---|---|---|---|---|
| | | m=1 | m=0 | |
| | 1918. | *cal.* | *cal.* | *cal.* |
| Lincoln, Nebr. | Feb. 3 | 1.54 | 1.71 | ..... |
| Lincoln, Nebr. | Feb. 16 | 1.52 | 1.73 | ..... |
| Santa Fe, N. Mex. | Feb. 1 | 1.62 | 1.84 | 1.92 |
| Santa Fe, N. Mex. | Feb. 9 | 1.56 | 1.78 | 1.87 |

## NOCTURNAL RADIATION MEASUREMENTS.

By Prof. HERBERT H. KIMBALL.

[Dated: Washington, Feb. 19, 1918.]

### APPARATUS.

In making the nocturnal radiation measurements here summarized a modification of the Ångström electrical compensation instrument has been employed.[1] As is well known, the radiating surface in this instrument consists of two thin blackened strips of manganin. The rate at which these strips lose heat by radiation is determined by measuring the electric current that must be passed through them in order to maintain temperature equilibrium between them and two other strips of manganin similar to these in every way except that their surfaces are bright. The bright strips are exposed beside the blackened strips, and under exactly the same conditions.

*The pyrgeometer.*—Figure 1 shows the bright strips ($W$, $W$) and black strips ($B$, $B$) mounted on a hard rubber frame in the end of a nickel-plated tube. In order to determine when the four strips are in temperature equilibrium thermo-electric junctions ($j$, $j$) are provided at their backs, but electrically insulated from them. These junctions are connected in series in a circuit that also includes the coil of a delicate galvanometer, $G$. A slight temperature difference between the junctions back of the bright and the black strips, respectively, generates a current which, passing through the galvanometer coils, deflects them from their zero position. The blackened strips are then warmed by passing through them an electric current, which is adjusted to such strength that the galvanometer coils return to their zero position, indicating the establishment of the temperature equilibrium sought. Under these conditions the blackened strips are receiving the same amount of heat that is being lost by radiation, provided the bright strips are perfect reflectors and do not lose heat by radiation. Actually, however, the bright strips are imperfect reflectors and lose some heat by radiation. The electric heating current is therefore a measure of the difference in the radiating powers of the bright and the black strips. Such devices have been called pyrgeometers by A. Ångström (op. cit., p. 28).

The Weather Bureau has had four of these pyrgeometers constructed. Nos. 1, 2, and 3, had two blackened and two bright manganin strips, the bright strips being gold plated. Five silver-bismuth thermo-electric junctions are provided at the back of each strip, so that there are 10 warm and 10 cold junctions on each instrument. These junctions were made by Dr. W. W. Coblentz,[2] of the United States Bureau of Standards, who also prepared the bright and black strips and mounted them on sup-

[1] *Ångström, Knut.* Über die Anwendung der elektrischen Kompensationsmethode zur Bestimmung der nächtlichen Ausstrahlung. Nova acta, Regiæ societatis scientiarum Upsaliensis, Upsala, 1905, Ser. IV, vol. 1. N. 2.

[2] *Coblentz, W. W.* Instruments and methods used in radiometry. Bull., U. S. Bureau of Standards, 1913, **9**: 7–63.

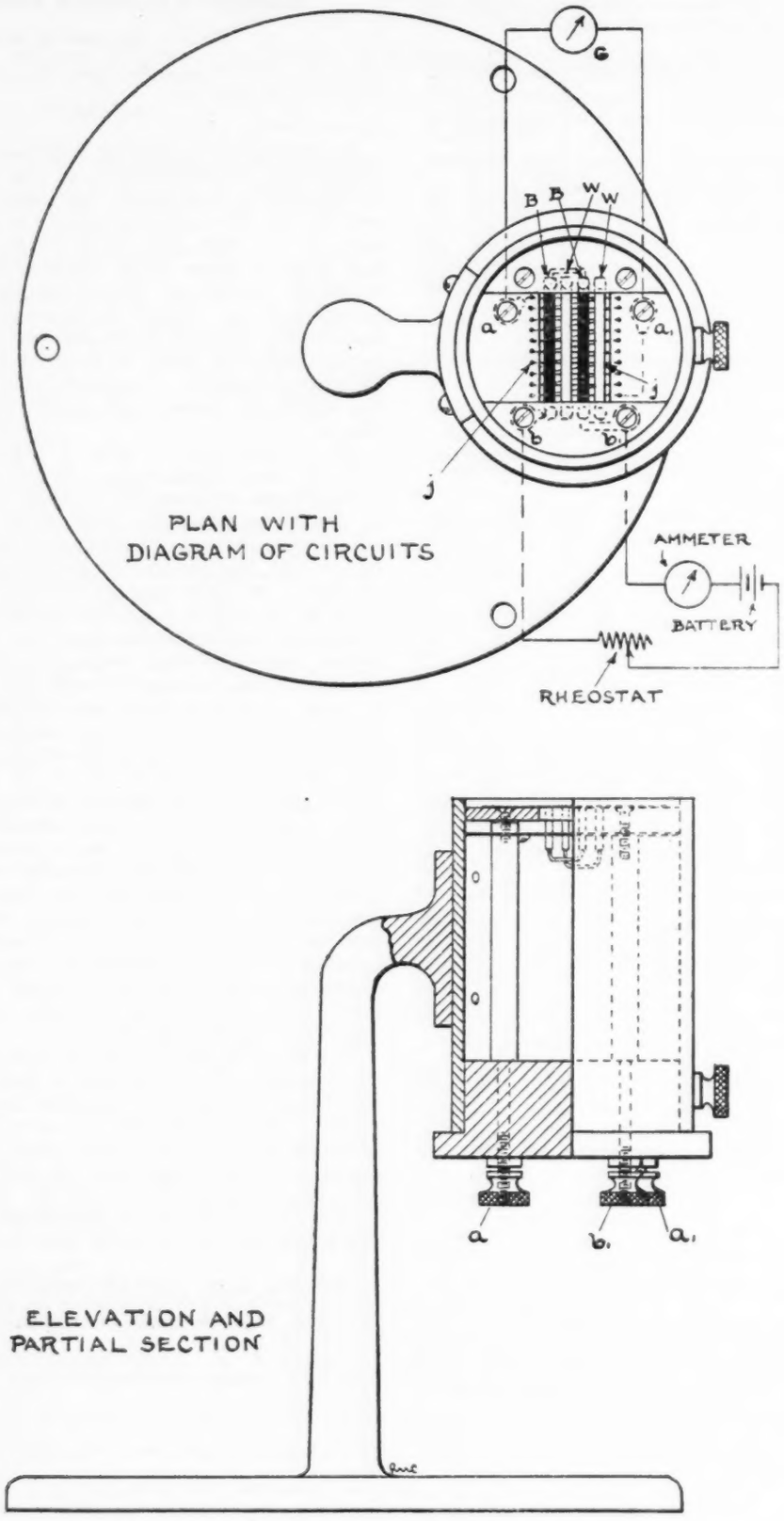


FIGURE 1.—The pyrgeometer, with diagram of electric circuits.

ports made up in the Weather Bureau machine shop. These strips are about 0.03mm. thick, 2mm. wide, and 20mm. long. The resistance of each strip is about 0.15 ohm, and that of the thermopile is about 3.5 ohms.

Instrument No. 1 was constructed in 1914 and used in measurements at Mount Weather, Va., and later at the American University, Washington, D. C. During March 1915, one of the fine bismuth wires of the thermopile was broken, and there was evidence that the gold-plated surfaces had been corroded by acid fumes from a drying mixture. These strips were therefore replaced by platinum strips, and the instrument was designated No. $1_{bis}$.

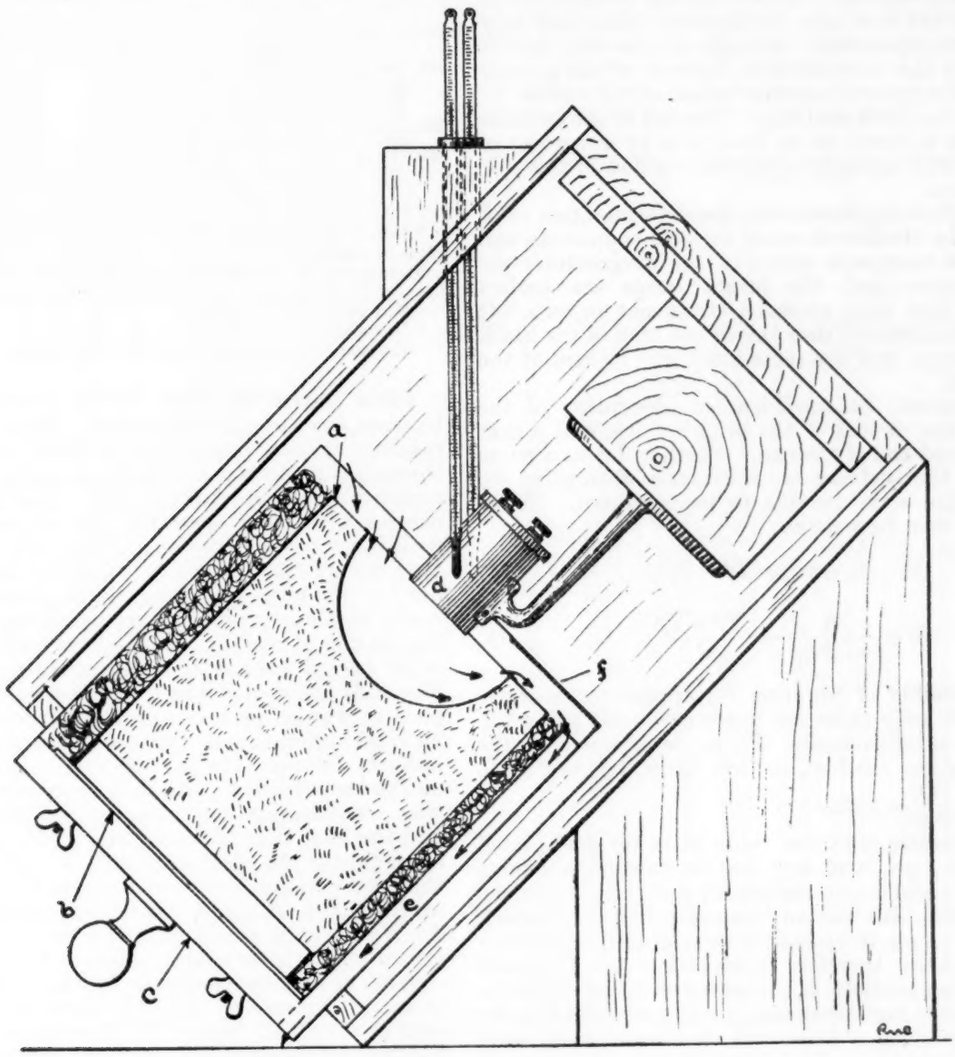


FIGURE 2.—Apparatus for standardizing pyrgeometers.

### STANDARDIZATION OF PYRGEOMETERS.

For determining the rate at which heat is exchanged by radiation between two black bodies we may make use of the Stefan-Boltsmann law

$$R = \sigma(T_1^4 - T_2^4), \qquad (1)$$

where $T_1$ and $T_2$ represent the absolute temperatures of the two bodies, and $\sigma$ is the radiation constant for a black body. The value of $\sigma$ is here assumed to be $5.7\times10^{-12}$ watts per square centimeter, or $8.18\times10^{-11}$ gram-calories per minute per square centimeter, a value 6½ per cent greater than that employed by both K. and A. Ångström.[3] If we represent by $i$ the amperage of the electric current required to maintain temperature equilibrium between the bright and black strips of the pyrgeometer we may also write

$$R = Ki^2 = \sigma(T_1^4 - T_2^4), \qquad (2)$$

in which $K$ is a constant depending upon the dimensions and the electrical resistance of the strips. Hence by measuring $T_1$, the temperature of the pyrgeometer, $T_2$, the temperature of that to which it is radiating, and $i$, the amperage of the heating current, we may determine $K$ with the degree of accuracy to which $\sigma$ is known.

*Standardizing apparatus.*—Figure 2 shows the character of the apparatus employed in standardizing the pyrgeometers. A copper can, $a$, is made up with a bottom that, viewed from the outside, contains a concave hemi-

[3] *Ångström, Anders.* A study of the radiation of the atmosphere. Smithsonian misc. coll., Washington, 1915, **65**, No. 3, p. 30.

spherical indentation, the surface of which is blackened by the smoke from burning camphor. The can is filled with a mixture of finely shaved ice and water, and the open end is closed by means of a rubber gasket, *b*, under a wooden cover, *c*, that is drawn down tight. The can is placed inside a cylinder of tin, and the annular space between is filled with hair. The blackened end of the can is inserted in a box, as shown in figure 2, which is tilted at an angle of about 45°. The pyrgeometer to be standardized, *d*, is then exposed to the blackened cup-like depression in the end of the can, with the strips just even with the edge of the cup. An electric fan is employed to force air into the box near the bottom. This not only equalizes air temperatures throughout the box, but it also facilitates the outward flow, by way of the passage *e*, provided through the annular space, of air cooled by contact with the blackened cup. The end of the cylinder inside the box is closed on its lower side by a segment of tin, as shown at *f*, figure 2, to prevent the flow of this cold air into the box.

Equation (2) is applicable for the determination of $K$ only in case the blackened end of the cold copper can and the blackened manganin strips of the pyrgeometer are perfect radiators and the bright strips are perfect reflectors, so that their emission coefficient is zero. It has already been stated that this is not true of the black and bright strips, and the same must also be said of the blackened can.

Let $n$ represent the coefficient of absorption of the blackened strips, $m$ that of the bright strips, and $p$ that of the blackened end of the can. Further, let us assume that none of the surfaces are selectively absorptive for radiation of the wave lengths to be measured. Equation (2) may then be written

$$Ki^2=(n-m)p\sigma(T_1^4-T_2^4), \tag{3}$$

from which

$$K'=\frac{K}{(n-m)p}=\sigma\frac{T_1^4-T_2^4}{i^2}. \tag{4}$$

The last member of equation (3) applies to measurements of black-body radiation if $p$ is given the value 1.0. But for such measurements, $K'$, as determined by the above calibration method, is too large by the ratio $\frac{1.0}{p}$, or about $\frac{1.0}{0.98}=1.02$.

Ångström [4] states that the value of $m$ for gold-plated strips is about 3 per cent, and that because of this value the strips will remain at a temperature slightly below the air temperature. We wish to determine the rate at which a black body at air temperature loses heat by radiation to the atmosphere; therefore, in equation (3), $T_1$ should represent the temperature of the air surrounding the body. In the calibration measurements the temperature was determined by placing a mercurial thermometer on each side of the instrument. One thermometer was where it could radiate freely to the cold can, and the other was somewhat shielded from it by the instrument. A part of the time a resistance thermometer was placed inside the case of the instrument, and just back of the thermopile. Unfortunately, suitable terminals were not provided for this thermometer and it was found, after a time, that in transferring it from one instrument to another its resistance had been diminished, so that its temperature indications were too low.

[4] *Ångström, Anders.* Opus cit., p. 31.

During most of the tests a small screen was placed between the bulbs of the mercurial thermometers and the cold can.

TABLE 1.—*Comparisons of temperatures measured by a resistance thermometer inside the case of the pyrgeometer, and by mercurial thermometers on each side of the instrument.*

| Date. | Thermometers. | | |
|---|---|---|---|
| | Resistance. | Mercurial beside instrument. | Mercurial behind instrument. |
| 1915. | °C. | °C. | °C. |
| Jan. 30 [a] | 19.46 | 19.59 | 20.67 |
| 30 [a] | 19.28 | *20.29 | 20.63 |
| 30 | 19.08 | *19.82 | 20.18 |
| 30 [a] | 18.97 | 19.20 | 20.34 |
| Feb. 19 [b] | [c] 21.78 | †21.77 | †22.09 |
| 19 [b] | [c] 20.94 | 21.38 | 21.46 |
| Mar. 2 [b] | [c] 13.97 | †14.63 | †14.77 |
| 3 [b] | [c] 18.80 | 18.91 | 18.93 |
| 3 [b] | [c] 18.60 | 19.05 | 19.15 |

*Bulb of thermometer shielded from cold surface of can by a small plate of aluminum.

†Bulbs of both thermometers shielded from cold surface of can by sheet of blotting paper.

[a] Box thoroughly ventilated.

[b] Box slightly ventilated.

[c] Resistance thermometer covered with tinfoil.

Table 1 gives the most reliable synchronous readings between the three thermometers. From these and other readings it was found that a slight movement of air through the box was necessary, in order to prevent temperature gradients in the box. Furthermore, it was necessary to make sure that the air cooled by contact with the cup-like depression in the end of the can flowed outward by the passage provided for that purpose, and not into the box. Likewise, it was necessary to maintain nearly stationary temperature conditions in the box during a series of readings, as the temperature of the instrument lagged behind the temperature of the air. At Mount Weather this was easily accomplished, as the apparatus was set up in a constant temperature room; but at Washington it was difficult to maintain a sufficiently uniform temperature in the box. Care was necessary also to keep the dew-point in the box below 0° C, as otherwise condensation took place on the cold end of the can, and the heat thus liberated materially modified the rate of cooling of the blackened surface. At Mount Weather this also was accomplished without difficulty by forcing air through a drying tube before its entrance into the box. At Washington it has been practicable to make standardization tests on cold dry winter days only.

With the above conditions fulfilled the mercurial thermometer exposed to the cold blackened end of the can read about 0.2° C. higher than the resistance thermometer inside the case of the instrument, and the shielded mercurial thermometer read about half a degree higher. These temperature differences, under the conditions of the tests, caused differences of about 1 per cent and 3 per cent, respectively, in the measured rates of radiation. The latter is Ångström's estimate, referred to above, for the emission coefficient of the gold-plated strips. The temperature of the air about the instrument undergoing test, or $T_1$, has therefore been assumed to be that of the shielded thermometers, and the temperature of the blackened cup-like end of the ice-filled can, or $T_2$, has been assumed to be 0° C.

TABLE 2.—*Summary of standardizations of pyrgeometers.*

| Number 1. | | | Number $1_{bis}$. | | | Number 2. | | | Number 3. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date. | $T$. | $K'$. | Date. | $T$. | $K'$. | Date. | $T$. | $K'$. | Date. | $T$. | $K'$. |
| *1914.* | | | *1915.* | | | *1914.* | | | *1914.* | | |
| May 8 | 288.2 | 9.09 | Mar. 23 | 287.6 | 7.47 | Mar. 2 | 292.7 | 7.50 | Mar. 2 | 287.7 | 6.72 |
| 8 | 288.1 | 9.08 | 23 | 287.8 | 7.54 | 3 | 290.2 | 7.44 | 3 | 291.0 | 6.51 |
| 8 | 288.0 | 9.39 | 23 | 287.8 | 7.58 | ..... | ..... | ..... | ..... | ..... | ..... |
| 14 | 288.9 | 8.95 | 23 | 288.2 | 7.24 | ..... | ..... | ..... | ..... | ..... | ..... |
| 14 | 288.7 | 9.38 | 23 | 288.7 | 7.33 | ..... | ..... | ..... | ..... | ..... | ..... |
| 14 | 288.6 | 9.57 | 23 | 289.5 | 7.45 | ..... | ..... | ..... | ..... | ..... | ..... |
| 14 | 288.4 | 9.54 | 23 | 289.7 | 7.47 | ..... | ..... | ..... | ..... | ..... | ..... |
| 14 | 288.4 | 9.54 | 23 | 289.7 | 7.47 | ..... | ..... | ..... | ..... | ..... | ..... |
| 14 | 288.2 | 9.55 | | | | | | | | | |
| 14 | 288.1 | 9.55 | *1916.* | | | | | | | | |
| 14 | 288.1 | 9.60 | Feb. 4 | 287.9 | 7.24 | ..... | ..... | ..... | ..... | ..... | ..... |
| 14 | 288.1 | 9.43 | 4 | 287.3 | 7.35 | ..... | ..... | ..... | ..... | ..... | ..... |
| 22 | 289.2 | 8.80 | 4 | 287.2 | 7.52 | ..... | ..... | ..... | ..... | ..... | ..... |
| 22 | 289.0 | 8.75 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 22 | 288.9 | 8.84 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 22 | 288.4 | 9.17 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 22 | 288.4 | 9.21 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 22 | 288.4 | 9.21 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Means | ..... | 9.24 | ..... | ..... | 7.42 | ..... | ..... | 7.47 | ..... | ..... | 6.62 |
| Corrected for $p$. | | 9.1 | By comparative readings. | | 7.42 | ..... | ..... | 7.3 | ..... | ..... | 7.0 |
| *1915.* | | | | | | | | | | | |
| Mar. 2 | 291.6 | 9.86 | Corrected for $p$ | | 7.3 | ..... | ..... | 7.2 | ..... | ..... | 6.9 |
| 2 | 290.5 | 9.92 | | | | | | | | | |
| Mean | ..... | 9.89 | | | | | | | | | |
| Corrected for $p$. | | 9.7 | | | | | | | | | |

In Table 2 are summarized the standardization measurements on the different instruments. At the American University, in Washington, during March and April, 1915, and in North Carolina, during May, 1915, numerous comparisons were made between pyrgeometers Nos. $1_{bis}$, 2, and 3. The ratios of the radiation measurements by these instruments, reduced to heat units by the use of the mean values of $K'$ determined by standardization tests, are given in Table 3. From these ratios it appears that the value of $K'$ for pyrgeometer No. 2 as thus determined is too high, and that determined for No. 3 is too low. The values of $K'$ derived from these comparisons are also given in Table 2, and, finally, the adopted values, obtained by correcting the above for the error due to the fact that the value of $p$ is about 0.98 instead of 1.0.

TABLE 3.—*Comparisons of pyrgeometers.*

| Stations. | Ratios of radiation measurements. | | |
|---|---|---|---|
| | No. 2 / No. $1_{bis}$ | No. 3 / No. $1_{bis}$ | No. 3 / No. 2 |
| Washington, D. C. | 1.01 | 0.936 | 0.940 |
| North Carolina. | 1.03 | 0.926 | 0.940 |

It seems probable that the high value of $K'$ obtained for pyrgeometer No. 1 is due to the fact that the surfaces of the bright strips were corroded by fumes from a drying mixture before the tests were made at Mount Weather. The restandardization tests made in Washington in March, 1915, indicate that the corrosion had progressed in the meantime. The factor $K'=9.1$ was used in reducing all observations obtained at Mount Weather between May and September, 1914, however, and the factor $K=9.7$ in reducing the observations obtained at the American University in Washington between December, 1914, and March, 1915.

In August, 1917, Smithsonian pyranometer[5] No. 2 was compared with pyrgeometers Nos. 1 and 3. The former was greatly disturbed by wind currents, so that the results were quite inconclusive. The pyranometer sometimes read higher and sometimes lower than the pyrgeometers.

## NOCTURNAL RADIATION MEASUREMENTS AT MOUNT WEATHER, VA., AND WASHINGTON, D. C.

In Table 4 are summarized the radiation measurements made at Mount Weather, Va., with pyrgeometer No. 1. The instrument was exposed on the capstone of the ventilating flue of the physical laboratory, and there was practically no obstruction between it and the sky in any direction down to the true horizon.[6] The elevation above sealevel was about 540 meters.

TABLE 4.—*Summary of nocturnal radiation measurements at Mount Weather, Va.*

[Gram-calories per minute per square centimeter.]

| Date. | Time. | $E$. | $t$. | $e$. | Remarks. |
|---|---|---|---|---|---|
| 1914. | *H. m.* | *cal.* | *°C.* | *mm.* | |
| May 14 | 10:37 p. | 0.129 | 11.1 | 5.56 | Stars shining; St.Cu. |
| 14 | 11:02 p. | 0.078 | 10.9 | 5.79 | Cloudiness increasing. |
| 18 | 8:30 p. | 0.205 | 16.8 | 5.16 | Light haze. |
| 18 | 11:06 p. | 0.202 | 16.2 | 4.95 | Indications of Ci. |
| 18 | 11:53 p. | 0.202 | 15.9 | 4.57 | |
| 19 | 1:08 a. | 0.205 | 15.9 | 4.37 | |
| 19 | 2:20 a. | 0.205 | 15.6 | 4.57 | |
| 19 | 8:40 p. | 0.208 | 18.7 | 4.95 | Dense haze. |
| 20 | 2:44 a. | 0.197 | ..... | ..... | |
| 20 | 2:59 a. | 0.194 | 16.7 | 4.95 | |
| 20 | 3:12 a. | 0.193 | ..... | ..... | |
| 20 | 3:36 a. | 0.192 | ..... | ..... | |
| 20 | 4:00 a. | 0.193 | 16.7 | 5.16 | |
| 20 | 4:18 a. | 0.192 | ..... | ..... | |
| 20 | 4:50 a. | 0.186 | 16.3 | 4.85 | |
| 20 | 8:15 p. | 0.190 | 23.6 | 5.16 | Dense haze. |
| 21 | 8:32 p. | 0.183 | ..... | ..... | Stars shining; some Ci.St. |
| 21 | 8:52 p. | 0.183 | 22.3 | 7.70 | Do. |
| 22 | 8:22 p. | 0.152 | ..... | ..... | 10/10 St.Cu. at 8 p. m. obs.; cleared later |
| 22 | 8:34 p. | 0.153 | 20.8 | 7.87 | |
| 23 | 8:32 p. | 0.176 | 18.1 | 4.17 | 6/10 Ci. at 8 p. m. |
| 24 | 8:56 p. | 0.147 | 17.8 | 6.76 | 4/10 Ci.St. at 8 p. m. |
| 27 | 8:30 p. | 0.069 | ..... | ..... | 7/10 A.Cu. |
| 27 | 8:40 p. | 0.091 | 25.6 | 11.81 | 3/10 A.Cu. |
| 28 | 8:36 p. | 0.110 | 24.4 | 14.60 | 5/10 St.Cu. |
| 31 | 8:39 p. | 0.173 | 20.0 | 8.48 | 2/10 A.St.; light smoke. |
| June 2 | 8:49 p. | 0.219 | 18.3 | 4.75 | Ci.St. clouds at sunset. |
| 3 | 2:37 a. | 0.191 | 17.8 | 4.37 | Light haze. |
| 3 | 3:04 a. | 0.199 | 17.8 | 4.37 | |
| 3 | 3:29 a. | 0.203 | 16.9 | 4.57 | |
| 3 | 3:58 a. | 0.198 | 15.6 | 4.57 | |
| 3 | 4:11 a. | 0.198 | ..... | ..... | |
| 3 | 4:28 a. | 0.197 | 15.6 | 4.95 | |
| 3 | 4:50 a. | 0.190 | 15.6 | 4.57 | Ci.St. clouds at sunrise. |
| 5 | 8:34 p. | 0.165 | 16.7 | 5.79 | 5/10 Ci. 2/10 A.Cu. |
| 6 | 8:47 p. | 0.136 | 18.1 | 7.04 | 2/10 St.Cu.; some false cirrus. |
| 7 | 9:31 p. | 0.143 | 24.7 | 14.10 | 6/10 Ci. |
| 8 | 10:49 p. | 0.120 | 24.6 | 16.79 | 1/10 Cu.; 5/10 Ci. |
| 9 | 8:58 p. | 0.006 | 16.9 | 13.61 | 10/10 stratus. |
| 9 | 9:28 p. | 0.001 | 16.6 | 13.13 | 10/10 stratus; light fog. |
| 10 | 9:00 p. | 0.051 | 26.4 | 14.10 | 10/10 St.Cu. |
| 11 | 9:13 p. | 0.110 | 25.6 | 15.65 | 1/10 Ci. |
| 12 | 8:49 p. | 0.074 | 23.9 | 9.14 | 8/10 St.Cu. |
| 13 | 8:40 p. | 0.148 | 23.6 | 8.81 | 6/10 Ci. |
| 14 | ..... | ..... | ..... | ..... | Foggy. |
| 15 | 8:34 p. | 0.131 | 18.6 | 8.48 | 4/10 (Ci. and Cu.). |
| 16 | 8:40 p. | 0.201 | 16.7 | 4.17 | 1/10 Ci. |
| 17 | 8:46 p. | 0.188 | 16.9 | 6.27 | 3/10 Ci. |
| 18 | ..... | ..... | ..... | ..... | Rain. |
| 19 | 8:33 p. | 0.133 | 15.2 | 11.38 | 3/10 Ci.; 2/10 St.Cu. |
| 20 | 8:39 p. | 0.130 | 17.2 | 6.27 | 3/10 Ci. |
| 21 | 8:34 p. | 0.085 | 22.2 | 17.96 | 8/10 (A.Cu. and St.Cu.). |
| 22 | 8:52 p. | 0.052 | 22.8 | 14.10 | 10/10 St.Cu. |
| 23 | 8:45 p. | 0.078 | 23.3 | 15.11 | 9/10 St.Cu. |
| 24 | 8:46 p. | 0.117 | 28.1 | 17.37 | 1/10 Ci.; 1/10 A.Cu.; 1/10 St.Cu. |
| 27 | 10:25 p. | 0.182 | 22.2 | 16.20 | 1/10 Ci. |
| 28 | 8:32 p. | 0.130 | 25.0 | 16.79 | 3/10 A.Cu.; 2/10 St.Cu. |
| 29 | 8:54 p. | 0.144 | 16.2 | 8.81 | 2/10 Ci.; 2/10 A.Cu. |
| 30 | 9:06 p. | 0.151 | 19.4 | 8.48 | Ci.St. over most of sky. |

[5] *Abbot, C. G., & Aldrich, L. B.* The pyranometer—An instrument for measuring sky radiation. Smithsonian misc. col., Washington, 1916. **66**, No. 7.

[6] Views showing the character of the exposure at Mount Weather will be found in the MONTHLY WEATHER REVIEW for August, 1914, **42**, opposite p. 477, figs. 3 and 4.

TABLE 4.—*Summary of nocturnal radiation measurements at Mount Weather, Va.*—Continued.

| Date. | Time. | R. | t. | e. | Remarks. |
|---|---|---|---|---|---|
| 1914. | H. m. | cal. | °C. | mm. | |
| July 2 | 8:37 p. | 0.139 | 22.1 | 9.83 | 2/10 Ci.; 1/10 A.St.; 1/10 St. Cu. |
| 3 | 11:48 p. | 0.076 | 19.4 | 13.13 | 9/10 St.Cu. |
| 4 | ..... | ..... | ..... | ..... | Rain. |
| 5 | 8:34 p. | 0.107 | 17.2 | 13.13 | Light fog; 5/10 Ci. |
| 6 | 8:42 p. | 0.027 | 16.0 | 12.68 | 10/10 St. |
| 7 | 9:06 p. | 0.043 | 19.4 | 13.61 | 9/10 St.Cu. |
| 8 | 8:50 p. | 0.115 | 21.0 | 14.10 | 4/10 false cirrus. |
| 9 | 8:35 p. | 0.113 | 21.8 | 16.20 | 3/10 Ci. |
| 10 | 8:38 p. | 0.083 | 23.6 | 15.37 | 10/10 A.St.; clearing. |
| 11 | 9:05 p. | 0.073 | 25.6 | 14.60 | 6/10 St.Cu. |
| 12 | 8:34 p. | 0.124 | 26.9 | 12.68 | 3/10 Ci. |
| 13 | 8:37 p. | 0.068 | 20.8 | 14.10 | 10/10 St.Cu. |
| 14 | ..... | ..... | 21.4 | 17.37 | 10/10 St.Cu.; rain. |
| 15 | 8:36 p. | 0.088 | 23.3 | 18.59 | 4/10 Ci.St.; 1/10 St.Cu. |
| 16 | 8:49 p. | 0.078 | 24.2 | 15.65 | 8/10 St. Cu. |
| 17 | 8:53 p. | 0.094 | 25.6 | 16.20 | 1/10 Ci. |
| 18 | 8:50 p. | 0.147 | 22.8 | 10.97 | Few A.St. |
| 19 | 9:02 p. | 0.157 | 18.9 | 9.14 | Few A.St.; dense haze. |
| 20 | 8:39 p. | 0.125 | 21.4 | 11.81 | Few Fr.Cu. |
| 21 | 9:05 p. | 0.138 | 26.3 | 10.59 | Light haze. |
| 22 | 9:20 p. | 0.104 | 23.9 | 15.65 | 2/10 Ci. |
| 23 | 9:03 p. | 0.059 | 28.5 | 11.81 | 10/10 St.Cu. |
| 24 | ..... | ..... | ..... | ..... | Rain. |
| 25 | 11:03 p. | 0.086 | 25.8 | 15.11 | 1/10 Ci. |
| 26 | 8:46 p. | 0.072 | 24.4 | 16.79 | 2/10 Ci. |
| 27 | 9:32 p. | 0.103 | 26.4 | 13.61 | 5/10 A.St. |
| 28 | 8:31 p. | 0.140 | 16.8 | 10.97 | 1/10 A.St. and St.Cu. |
| 29 | 9:41 p. | 0.099 | 16.3 | 8.18 | 7/10 St.Cu. |
| 30 | 9:22 p. | 0.135 | 13.3 | 9.83 | 4/10 St.Cu. |
| 31 | 8:42 p. | 0.130 | 19.4 | 7.87 | 3/10 A.Cu. |
| Aug. 1 | 8:50 p. | 0.141 | 22.2 | 8.48 | No clouds. |
| 3 | 8:54 p. | 0.133 | 19.7 | 11.38 | 2/10 Ci.St. |
| 4 | 8:46 p. | 0.107 | 19.4 | 12.68 | 3/10 Ci. |
| 5 | 9:16 p. | 0.102 | 19.3 | 13.13 | 1/10 Ci.St.; 1/10 A.Cu.; dense haze. |
| 6 | 9:35 p. | 0.110 | 21.1 | 15.65 | 1/10 Ci.St.; dense haze. |
| 7 | 8:40 p. | 0.126 | 25.7 | 14.60 | 3/10 St.Cu.; dense haze. |
| 8 | 8:37 p. | 0.118 | 26.8 | 15.11 | 4/10 St.Cu. |
| 9 | 8:38 p. | 0.070 | 26.6 | 16.20 | 10/10 St.Cu. |
| 10 | 8:48 p. | 0.049 | 22.5 | 15.93 | 9/10 St.Cu. |
| 11 | 8:22 p. | 0.040 | 22.4 | 16.20 | 10/10 St.Cu. |
| 12 | 9:28 p. | 0.100 | 17.1 | 13.61 | 2/10 St. |
| 13 | 10:00 p. | 0.143 | 20.0 | 9.47 | No clouds visible. |
| 14 | 8:22 p. | 0.116 | 23.9 | 13.13 | 1/10 Ci.;3/10 St. Cu. |
| 15 | 8:40 p. | 0.147 | 21.3 | 7.29 | Few clouds on horizon. |
| 16 | 8:20 p. | 0.126 | 22.8 | 10.21 | 3/10 Ci. (over whole sky). |
| 17 | 9:52 p. | 0.137 | 24.2 | 10.59 | Few clouds. |
| 18 | 8:28 p. | 0.136 | 26.9 | 13.13 | Few cirrus. |
| 19 | 9:32 p. | 0.110 | 26.8 | 14.60 | No clouds visible; stars faint. |
| 21 | 8:28 p. | 0.094 | 22.3 | 13.61 | 4/10 A.Cu. |
| 22 | 8:52 p. | 0.147 | 22.4 | 9.47 | Light haze. |
| 23 | 9:24 p. | 0.146 | 26.0 | 15.11 | No clouds visible. |
| 29 | 8:22 p. | 0.070 | 23.4 | 14.10 | 6/10 St.Cu.; distant lightning. |
| 30 | 8:18 p. | 0.124 | 21.1 | 11.38 | Dense lower haze. |
| 31 | 10:12 p. | 0.116 | 22.8 | 12.68 | 5/10 Ci. |
| Sept. 1 | 8:08 p. | 0.119 | 25.1 | 15.65 | 4/10 Ci. |
| 2 | 8:02 p. | 0.028 | 26.8 | 15.65 | 9/10 St.Cu. |
| 3 | 8:28 p. | 0.158 | 21.8 | 8.48 | 2/10 Ci.Cu., A.Cu. and St.Cu. |
| 4 | 8:07 p. | 0.147 | 14.2 | 8.81 | Few St.Cu. |
| 5 | 8:44 p. | 0.149 | 17.9 | 8.18 | 2/10 Ci. |
| 6 | 7:53 p. | 0.084 | 23.5 | 12.24 | 5/10 A.Cu. and St.Cu. |
| 7 | 8:14 p. | 0.137 | 21.8 | 9.83 | 2/10 Ci. |
| 8 | 8:02 p. | 0.114 | 14.5 | 7.29 | 3/10 A.Cu.; 5/10 St.Cu. |
| 9 | 7:56 p. | 0.167 | 12.1 | 4.75 | No clouds. |
| 10 | 9:32 p. | 0.139 | 14.5 | 5.79 | 5/10 Ci. |
| 13 | 7:52 p. | 0.135 | 12.7 | 7.57 | No clouds. |
| 14 | 8:20 p. | 0.138 | 12.8 | 8.18 | Do. |
| 15 | 8:52 p. | 0.169 | 14.3 | 6.76 | Do. |
| 15 | 10:32 p. | 0.155 | 13.9 | 7.29 | Do. |
| 16 | 12:54 a. | 0.146 | 11.2 | 8.58 | Do. |
| 16 | 2:23 a. | 0.118 | 11.1 | 9.47 | 5/10 A.St. |
| 16 | 8:08 p. | 0.108 | 15.9 | 10.62 | 4/10 Ci. |
| 17 | 8:16 p. | 0.064 | 19.1 | 10.21 | 6/10 Ci.St. |
| 18 | 8:00 p. | 0.160 | 22.6 | 9.83 | 1/10 St.Cu. |
| 19 | ..... | ..... | ..... | ..... | Rain. |
| 20 | 7:34 p. | 0.105 | 20.7 | 10.21 | 1/10 Ci. |
| 21 | 7:40 p. | 0.147 | 24.4 | 13.13 | 1/10 Ci. |
| 22 | 7:53 p. | 0.148 | 25.7 | 12.24 | 1 Ci. |
| 23 | 10:04 p. | 0.123 | 24.3 | 14.10 | 2/10 Cu.Ni. |
| 24 | ..... | ..... | ..... | ..... | Rain. |
| 25 | 7:38 p. | 0.138 | 13.9 | 8.18 | 2/10 A.St. & St.Cu. |
| 26 | 7:33 p. | 0.147 | 11.8 | 5.56 | Clear. |
| 27 | 7:32 p. | 0.075 | 16.5 | 6.04 | 6/10 St.Cu. |
| 28 | 7:28 p. | 0.146 | 13.6 | 3.81 | Few Fr.Cu. |
| 29 | 7:32 p. | 0.157 | 14.5 | 5.79 | Few Ci.St.; dense haze. |
| 30 | 7:34 p. | 0.150 | 17.2 | 6.50 | Clear. |

In Table 5 are summarized the radiation measurements made at the American University, Washington, D. C. Pyrgeometer No. 1 was employed in the measurements up to the end of January, 1915, but after that date most of the readings were made while comparing pyrgeometers Nos. $1_{bis}$, 2, and 3. The instruments were exposed on the capstone of a ventilating flue of the College of History, at an elevation of about 137 meters above sea level. The exposure compares favorably with that at Mount Weather.

The instruments were usually placed in position about sunset, but the metal cap was not removed to expose the strips until just before the readings were made. About five determinations of $i$ were usually obtained in each series of readings, and the values of $R$ given in the tables were computed from the means of these readings. Both $t$ and $e$ were obtained from readings of a sling psychrometer whirled on the roof near the pyrgeometers.

TABLE 5.—*Summary of nocturnal radiation measurements made at Washington, D. C.*

[Gram-calories per minute per square centimeter.]

| Date. | Time. | R. | t. | e. | Remarks. |
|---|---|---|---|---|---|
| 1914. | H. m. | cal. | °C. | mm. | |
| Dec. 14 | 6:00 p. | 0.162 | − 4.5 | 1.69 | |
| 15 | 6:02 p. | 0.156 | − 8.3 | 1.78 | |
| 16 | 6:04 p. | 0.152 | − 5.5 | 1.69 | Clouds on horizon. |
| 16 | 8:07 p. | 0.130 | − 6.5 | 1.31 | Trace of clouds on horizon. |
| 17 | 6:00 p. | 0.153 | − 2.3 | 1.07 | Few Ci. |
| 18 | 6:05 p. | 0.143 | 0.6 | 1.96 | Few clouds on horizon. |
| 26 | 6:05 p. | 0.152 | − 9.3 | 1.31 | |
| 26 | 8:27 p. | 0.146 | −11.5 | 1.07 | |
| 27 | 6:06 p. | 0.128 | − 5.1 | 1.87 | |
| 27 | 7:14 p. | 0.118 | − 5.7 | 1.60 | 1/10 clouds in west. |
| 1915. | | | | | |
| Jan. 8 | 6:42 p. | 0.156 | 4.9 | 3.99 | |
| 8 | 7:44 p. | 0.155 | 4.6 | 3.99 | |
| 9 | 6:12 p. | 0.142 | 7.3 | 4.75 | Very hazy on horizon. |
| 15 | 6:22 p. | 0.183 | 7.8 | 3.81 | |
| 15 | 7:18 p. | 0.172 | 6.6 | 3.81 | |
| 29 | 6:52 p. | 0.160 | − 0.4 | 2.36 | |
| 29 | 7:16 p. | 0.159 | ..... | ..... | |
| 29 | 7:54 p. | 0.158 | − 1.9 | 2.16 | Few A.St.; zenith clear |
| Mar. 9 | 8:27 p. | 0.184 | 3.4 | 2.74 | |
| 9 | 9:29 p. | 0.173 | ..... | ..... | |
| 9 | 9:44 p. | 0.172 | 3.3 | 2.87 | |
| 9 | 10:12 p. | 0.172 | ..... | ..... | |
| 9 | 10:41 p. | 0.175 | ..... | ..... | |
| 10 | 12:02 a. | 0.175 | 3.2 | 2.74 | |
| 10 | 12:21 a. | 0.159 | ..... | ..... | |
| 10 | 12.40 a. | 0.158 | ..... | ..... | |
| 10 | 12:52 a. | 0.166 | ..... | ..... | |
| 10 | 1:36 a. | 0.164 | ..... | ..... | |
| 10 | 1:53 a. | 0.162 | 2.3 | 2.62 | |
| 10 | 2:52 a. | 0.157 | ..... | ..... | |
| 10 | 3:10 a. | 0.159 | ..... | ..... | |
| 10 | 3:34 a. | 0.155 | ..... | ..... | |
| 10 | 3:53 a. | 0.152 | 1.0 | 2.87 | |
| 10 | 4:20 a. | 0.158 | ..... | ..... | |
| 10 | 4:35 a. | 0.165 | 1.7 | 3.81 | |
| 10 | 5:04 a. | 0.165 | ..... | ..... | |
| 10 | 5:22 a. | 0.163 | 0.7 | 3.00 | |
| 10 | 5:32 a. | 0.158 | ..... | ..... | |
| 12 | 8:07 p. | 0.176 | 0.9 | 2.49 | |
| 12 | 9:41 p. | 0.177 | ..... | ..... | |
| 12 | 9:56 p. | 0.188 | ..... | ..... | |
| 12 | 10:17 p. | 0.194 | 1.2 | 1.69 | |
| 12 | 10:36 p. | 0.193 | ..... | ..... | |
| 12 | 10:45 p. | 0.180 | 0.6 | 2.06 | |
| 12 | 11:23 p. | 0.206 | ..... | ..... | Radiation unsteady. |
| 12 | 11:56 p. | 0.205 | ..... | ..... | |
| 13 | 12:21 a. | 0.202 | ..... | ..... | |
| 13 | 12:36 a. | 0.189 | ..... | ..... | |
| 13 | 12:54 a. | 0.188 | −1.1 | 2.48 | |
| 13 | 1:20 a. | 0.175 | ..... | ..... | |
| 13 | 1:37 a. | 0.179 | ..... | ..... | |
| 13 | 2:14 a. | 0.178 | ..... | ..... | |
| 13 | 2:52 a. | 0.168 | −1.1 | 1.87 | |
| 13 | 3:19 a. | 0.172 | ..... | ..... | |
| 13 | 3:45 a. | 0.172 | ..... | ..... | |
| 13 | 4:08 a. | 0.167 | −1.1 | 1.96 | |
| 13 | 4:35 a. | 0.169 | ..... | ..... | |
| 13 | 4:47 a. | 0.166 | ..... | ..... | |
| 13 | 5:15 a. | 0.161 | ..... | ..... | |
| 13 | 5:26 a. | 0.162 | −1.7 | 1.78 | |
| 13 | 5:42 a. | 0.166 | ..... | ..... | |
| 14 | 8:00 p. | 0.180 | 8.3 | 3.63 | |
| 26 | 8:06 p. | 0.177 | 2.2 | 1.78 | Cirrus formed after series. |
| 27 | 8:13 p. | 0.201 | 4.2 | 2.49 | Hazy on horizon. |
| 27 | 8:25 p. | 0.181 | ..... | ..... | |
| 31 | 8:06 p. | 0.167 | 3.3 | 3.45 | Clouds forming. |
| Apr. 4 | 8:12 p. | 0.185 | 8.4 | 2.99 | |
| 4 | 8:29 p. | 0.191 | ..... | ..... | |
| 13 | 8:17 p. | 0.156 | 7.7 | 5.16 | |
| 13 | 8:30 p. | 0.152 | ..... | ..... | |
| 14 | 8:09 p. | 0.176 | 12.7 | 3.54 | Few clouds on horizon. |
| 14 | 8:24 p. | 0.193 | ..... | ..... | |
| 17 | 8:44 p. | 0.193 | 13.5 | 3.63 | |
| 21 | 9:50 p. | 0.145 | 16.2 | 5.36 | Thin clouds; smoke. |
| 24 | 8:28 p. | 0.143 | 24.4 | 10.97 | |
| 24 | 8:51 p. | 0.142 | ..... | ..... | |
| 24 | 9:51 p. | 0.134 | ..... | ..... | |
| 24 | 10:00 p. | 0.134 | ..... | ..... | |
| 24 | 10:40 p. | 0.134 | ..... | ..... | |

In Table 6 the measurements made when the sky was apparently cloudless, or when at most only a few cirrus were visible, are grouped in accordance with the surface vapor pressure. There are also included in this table some measurements made on the top of Peak Knob, Ellijay, N. C., that are given in more detail in Table 9. But few of the above observations were taken under ideal sky conditions, however. Reference to "Remarks" in Tables 4, 5, and 9 will show that at some time on almost every night there were indications of the presence of clouds. While, therefore, it would be unwise to attempt to establish radiation laws from these observations, a consideration of their relation to laws already advanced will be of interest.

TABLE 6.—*Summary of clear-sky nocturnal radiations measurements.*

| Date. | $e$. | $T_1$. | $R$. | $\sigma T_1^4$. | $R/\sigma T_1^4$ | $\Delta T$. | $R_{aa}$. |
|---|---|---|---|---|---|---|---|
| | *mm.* | °*C.* | *cal.* | *cal.* | | °*C.* | |
| Dec. 14 | 1.69 | 286.5 | 0.162 | 0.425 | 0.381 | −30.3 | 0.373 |
| 15 | 1.78 | 264.7 | 0.156 | 0.402 | 0.388 | −30.5 | 0.369 |
| 16 | 1.69 | 267.5 | 0.152 | 0.419 | 0.363 | −28.6 | 0.384 |
| 16 | 1.31 | 266.5 | 0.130 | 0.413 | 0.315 | −24.0 | 0.414 |
| 17 | 1.07 | 270.7 | 0.153 | 0.439 | 0.349 | −27.5 | 0.393 |
| 18 | 1.96 | 273.6 | 0.143 | 0.458 | 0.312 | −24.8 | 0.414 |
| 26 | 1.31 | 263.7 | 0.152 | 0.396 | 0.384 | −30.2 | 0.372 |
| 26 | 1.07 | 261.5 | 0.146 | 0.383 | 0.381 | −29.5 | 0.373 |
| 27 | 1.87 | 267.9 | 0.128 | 0.421 | 0.304 | −23.3 | 0.421 |
| 27 | 1.60 | 267.3 | 0.118 | 0.418 | 0.283 | −21.0 | 0.433 |
| **Means** | **1.54** | **267.2** | **0.144** | **0.417** | **0.346** | **−27.0** | **0.395** |
| Mar. 12 | 1.69 | 274.2 | 0.191 | 0.463 | 0.412 | −34.2 | 0.355 |
| 13 | 1.87 | 271.9 | 0.173 | 0.447 | 0.387 | −31.3 | 0.370 |
| 13 | 1.96 | 271.9 | 0.170 | 0.447 | 0.381 | −30.6 | 0.365 |
| 13 | 1.78 | 271.3 | 0.164 | 0.443 | 0.370 | −29.6 | 0.380 |
| 26 | 1.78 | 275.2 | 0.177 | 0.469 | 0.377 | −30.7 | 0.375 |
| **Means** | **1.82** | **272.9** | **0.175** | **0.454** | **0.385** | **−31.3** | **0.369** |
| Jan. 29 | 2.36 | 272.6 | 0.160 | 0.452 | 0.354 | −28.1 | 0.390 |
| 29 | 2.16 | 271.1 | 0.158 | 0.442 | 0.358 | −28.4 | 0.388 |
| Mar. 9 | 2.74 | 276.4 | 0.184 | 0.477 | 0.386 | −31.8 | 0.370 |
| 9 | 2.87 | 276.3 | 0.172 | 0.477 | 0.361 | −29.2 | 0.386 |
| 9 | 2.74 | 276.2 | 0.175 | 0.476 | 0.368 | −29.5 | 0.381 |
| 10 | 2.62 | 275.3 | 0.163 | 0.470 | 0.347 | −27.8 | 0.394 |
| 10 | 2.87 | 274.0 | 0.154 | 0.461 | 0.334 | −26.5 | 0.402 |
| 12 | 2.49 | 273.9 | 0.188 | 0.460 | 0.409 | −33.7 | 0.348 |
| 12 | 2.06 | 273.6 | 0.200 | 0.458 | 0.437 | −36.7 | 0.339 |
| 13 | 2.48 | 271.9 | 0.188 | 0.447 | 0.421 | −34.4 | 0.349 |
| 27 | 2.49 | 277.2 | 0.201 | 0.483 | 0.416 | −34.9 | 0.352 |
| Apr. 4 | 2.99 | 281.4 | 0.185 | 0.513 | 0.361 | −29.7 | 0.386 |
| **Means** | **2.57** | **275.0** | **0.177** | **0.468** | **0.379** | **−30.9** | **0.374** |
| Sept. 28 | 3.81 | 287.6 | 0.146 | 0.560 | 0.261 | −19.6 | 0.446 |
| Jan. 8 | 3.99 | 277.9 | 0.156 | 0.488 | 0.320 | −25.5 | 0.410 |
| 8 | 3.99 | 277.6 | 0.155 | 0.486 | 0.319 | −25.3 | 0.409 |
| 15 | 3.81 | 280.8 | 0.183 | 0.508 | 0.361 | −29.8 | 0.385 |
| 15 | 3.81 | 279.6 | 0.172 | 0.500 | 0.344 | −27.9 | 0.402 |
| Mar. 10 | 3.81 | 274.7 | 0.162 | 0.466 | 0.348 | −27.8 | 0.393 |
| 10 | 3.00 | 273.7 | 0.164 | 0.459 | 0.357 | −28.6 | 0.382 |
| 14 | 3.63 | 281.3 | 0.180 | 0.512 | 0.352 | −28.8 | 0.396 |
| 31 | 3.45 | 276.3 | 0.167 | 0.477 | 0.350 | −28.2 | 0.392 |
| Apr. 14 | 3.54 | 285.7 | 0.176 | 0.545 | 0.323 | −26.7 | 0.408 |
| 17 | 3.63 | 286.5 | 0.193 | 0.551 | 0.350 | −29.2 | 0.392 |
| **Means** | **3.68** | **280.2** | **0.169** | **0.505** | **0.335** | **−27.0** | **0.401** |
| May 18 | 4.95 | 289.2 | 0.202 | 0.572 | 0.353 | −29.0 | 0.390 |
| 18 | 4.57 | 288.9 | 0.202 | 0.570 | 0.354 | −29.9 | 0.389 |
| 19 | 4.37 | 288.9 | 0.205 | 0.570 | 0.360 | −30.5 | 0.386 |
| 19 | 4.57 | 288.6 | 0.205 | 0.567 | 0.362 | −30.6 | 0.394 |
| 19 | 4.95 | 291.7 | 0.208 | 0.592 | 0.351 | −29.9 | 0.391 |
| 20 | 4.95 | 289.7 | 0.194 | 0.576 | 0.337 | −28.3 | 0.400 |
| June 2 | 4.75 | 291.4 | 0.219 | 0.590 | 0.371 | −31.9 | 0.379 |
| 3 | 4.37 | 290.8 | 0.191 | 0.585 | 0.326 | −27.3 | 0.404 |
| 3 | 4.37 | 290.8 | 0.199 | 0.585 | 0.340 | −28.7 | 0.398 |
| 3 | 4.57 | 289.9 | 0.203 | 0.578 | 0.351 | −29.5 | 0.395 |
| 3 | 4.57 | 288.6 | 0.198 | 0.567 | 0.349 | −29.5 | 0.392 |
| 3 | 4.95 | 288.6 | 0.197 | 0.567 | 0.347 | −29.3 | 0.393 |
| 16 | 4.17 | 289.7 | 0.201 | 0.576 | 0.349 | −29.6 | 0.392 |
| Sept. 9 | 4.75 | 284.1 | 0.167 | 0.533 | 0.313 | −25.5 | 0.414 |
| May 5 | 4.95 | 285.2 | 0.169 | 0.541 | 0.312 | −25.5 | 0.414 |
| **Means** | **4.67** | **289.1** | **0.197** | **0.571** | **0.345** | **−29.1** | **0.396** |
| May 18 | 5.16 | 289.8 | 0.205 | 0.577 | 0.355 | −30.1 | 0.389 |
| 20 | 5.16 | 289.7 | 0.193 | 0.576 | 0.335 | −28.1 | 0.400 |
| 20 | 5.16 | 296.6 | 0.190 | 0.633 | 0.300 | −25.3 | 0.422 |
| Sept. 26 | 5.56 | 284.8 | 0.147 | 0.538 | 0.273 | −21.8 | 0.437 |
| 29 | 5.79 | 287.5 | 0.157 | 0.559 | 0.281 | −21.2 | 0.433 |
| Apr. 13 | 5.16 | 280.7 | 0.156 | 0.508 | 0.307 | −24.6 | 0.418 |
| May 5 | 5.16 | 286.3 | 0.177 | 0.549 | 0.322 | −26.6 | 0.399 |
| 5 | 5.16 | 285.8 | 0.178 | 0.546 | 0.326 | −26.8 | 0.416 |
| 5 | 5.16 | 285.2 | 0.172 | 0.541 | 0.318 | −26.0 | 0.411 |
| 10 | 5.61 | 280.2 | 0.177 | 0.504 | 0.351 | −28.7 | 0.391 |
| **Means** | **5.31** | **286.7** | **0.175** | **0.554** | **0.317** | **−25.9** | **0.412** |

TABLE 6.—*Summary of clear-sky nocturnal radiation measurements*—Con.

| Date. | $e$. | $T_1$. | $R$. | $\sigma T_1^4$. | $R/\sigma T_1^4$ | $\Delta T$. | $R_{aa}$ |
|---|---|---|---|---|---|---|---|
| | *mm.* | °*C.* | *cal.* | *cal.* | | °*C.* | |
| June 17 | 6.27 | 289.9 | 0.188 | 0.578 | 0.325 | −27.1 | 0.407 |
| Sept. 15 | 6.76 | 287.3 | 0.169 | 0.557 | 0.303 | −24.9 | 0.420 |
| 30 | 6.50 | 290.2 | 0.150 | 0.580 | 0.259 | −20.9 | 0.447 |
| May 9 | 6.76 | 283.0 | 0.146 | 0.525 | 0.278 | −22.1 | 0.435 |
| 9 | 6.76 | 282.4 | 0.146 | 0.521 | 0.280 | −22.3 | 0.432 |
| 9 | 6.68 | 281.9 | 0.150 | 0.517 | 0.290 | −23.0 | 0.428 |
| 9 | 6.68 | 281.3 | 0.152 | 0.512 | 0.297 | −23.8 | 0.424 |
| 9 | 6.60 | 281.9 | 0.150 | 0.517 | 0.290 | −23.0 | 0.428 |
| 10 | 6.27 | 282.4 | 0.159 | 0.520 | 0.306 | −24.7 | 0.418 |
| 10 | 6.71 | 281.9 | 0.153 | 0.517 | 0.296 | −23.6 | 0.424 |
| 10 | 6.07 | 280.2 | 0.173 | 0.504 | 0.343 | −27.9 | 0.396 |
| **Means** | **6.55** | **284.7** | **0.158** | **0.532** | **0.297** | **−23.9** | **0.424** |
| May 21 | 7.70 | 295.3 | 0.183 | 0.622 | 0.294 | −24.6 | 0.425 |
| 22 | 7.87 | 293.8 | 0.152 | 0.609 | 0.250 | −20.4 | 0.452 |
| June 6 | 7.04 | 291.1 | 0.136 | 0.587 | 0.232 | −18.7 | 0.464 |
| Aug. 15 | 7.29 | 294.3 | 0.147 | 0.614 | 0.239 | −19.4 | 0.459 |
| Sept. 13 | 7.57 | 285.7 | 0.135 | 0.545 | 0.248 | −19.6 | 0.454 |
| 15 | 7.29 | 286.9 | 0.155 | 0.554 | 0.280 | −22.6 | 0.434 |
| May 8 | 7.75 | 285.0 | 0.158 | 0.539 | 0.293 | −23.8 | 0.426 |
| 8 | 7.29 | 284.7 | 0.168 | 0.537 | 0.313 | −25.5 | 0.414 |
| 8 | 7.11 | 284.1 | 0.166 | 0.533 | 0.312 | −25.2 | 0.415 |
| 9 | 7.39 | 283.6 | 0.149 | 0.529 | 0.282 | −22.5 | 0.433 |
| 9 | 7.09 | 284.1 | 0.163 | 0.533 | 0.306 | −24.8 | 0.418 |
| **Means** | **7.40** | **288.1** | **0.156** | **0.564** | **0.277** | **−22.5** | **0.436** |
| May 31 | 8.48 | 293.0 | 0.173 | 0.603 | 0.287 | −23.7 | 0.430 |
| June 30 | 8.48 | 292.4 | 0.151 | 0.598 | 0.253 | −20.6 | 0.441 |
| Aug. 1 | 8.48 | 295.2 | 0.141 | 0.621 | 0.227 | −19.2 | 0.466 |
| Sept. 3 | 8.48 | 294.8 | 0.158 | 0.618 | 0.256 | −21.0 | 0.449 |
| 4 | 8.81 | 287.2 | 0.147 | 0.557 | 0.264 | −21.1 | 0.454 |
| 5 | 8.18 | 290.9 | 0.149 | 0.585 | 0.255 | −20.6 | 0.449 |
| 14 | 8.18 | 285.8 | 0.138 | 0.546 | 0.253 | −20.0 | 0.450 |
| 16 | 8.58 | 284.2 | 0.146 | 0.533 | 0.274 | −22.0 | 0.427 |
| 25 | 8.18 | 286.9 | 0.138 | 0.554 | 0.249 | −19.8 | 0.453 |
| July 19 | 9.14 | 291.9 | 0.157 | 0.594 | 0.264 | −21.6 | 0.444 |
| Aug. 13 | 9.47 | 293.0 | 0.143 | 0.603 | 0.237 | −17.8 | 0.460 |
| 22 | 9.47 | 295.4 | 0.147 | 0.623 | 0.236 | −19.2 | 0.461 |
| Sept. 7 | 9.83 | 294.8 | 0.137 | 0.618 | 0.222 | −17.8 | 0.469 |
| 18 | 9.83 | 295.6 | 0.160 | 0.625 | 0.256 | −21.1 | 0.449 |
| **Means** | **8.83** | **291.5** | **0.149** | **0.591** | **0.252** | **−20.4** | **0.450** |
| July 18 | 10.97 | 295.8 | 0.147 | 0.626 | 0.235 | −19.1 | 0.461 |
| 21 | 10.59 | 299.3 | 0.138 | 0.656 | 0.210 | −17.2 | 0.476 |
| 28 | 10.97 | 289.8 | 0.140 | 0.577 | 0.243 | −19.5 | 0.457 |
| Aug. 16 | 10.21 | 295.8 | 0.126 | 0.626 | 0.201 | −16.2 | 0.481 |
| 17 | 10.59 | 297.2 | 0.137 | 0.638 | 0.215 | −17.5 | 0.473 |
| July 20 | 11.81 | 294.4 | 0.125 | 0.614 | 0.204 | −16.3 | 0.480 |
| Aug. 3 | 11.38 | 292.7 | 0.133 | 0.600 | 0.222 | −17.7 | 0.469 |
| 30 | 11.38 | 294.1 | 0.124 | 0.612 | 0.203 | −16.1 | 0.481 |
| **Means** | **10.99** | **294.9** | **0.134** | **0.619** | **0.217** | **−17.4** | **0.472** |
| Sept. 22 | 12.24 | 298.7 | 0.148 | 0.651 | 0.227 | −18.7 | 0.466 |
| Aug. 18 | 13.13 | 299.8 | 0.136 | 0.662 | 0.205 | −16.8 | 0.480 |
| Sept. 21 | 13.13 | 297.4 | 0.147 | 0.640 | 0.230 | −18.8 | 0.465 |
| June 7 | 14.10 | 297.7 | 0.143 | 0.642 | 0.223 | −18.3 | 0.468 |
| **Means** | **13.15** | **298.4** | **0.144** | **0.649** | **0.221** | **−18.2** | **0.470** |
| June 11 | 15.65 | 298.6 | 0.110 | 0.650 | 0.169 | −13.6 | 0.500 |
| July 22 | 15.65 | 296.9 | 0.104 | 0.630 | 0.165 | −13.8 | 0.499 |
| 25 | 15.11 | 298.8 | 0.086 | 0.652 | 0.132 | −10.4 | 0.523 |
| Aug. 6 | 15.65 | 294.1 | 0.110 | 0.612 | 0.180 | −14.2 | 0.495 |
| 23 | 15.11 | 299.0 | 0.146 | 0.654 | 0.223 | −18.3 | 0.468 |
| June 8 | 16.79 | 297.6 | 0.120 | 0.642 | 0.187 | −15.0 | 0.490 |
| 27 | 16.20 | 295.2 | 0.182 | 0.621 | 0.293 | −24.3 | 0.426 |
| July 9 | 16.20 | 294.8 | 0.113 | 0.618 | 0.183 | −14.5 | 0.493 |
| 17 | 16.20 | 298.6 | 0.094 | 0.650 | 0.144 | −11.5 | 0.535 |
| 26 | 16.79 | 297.4 | 0.072 | 0.640 | 0.112 | − 8.7 | 0.535 |
| **Means** | **15.94** | **297.1** | **0.114** | **0.637** | **0.179** | **−14.4** | **0.494** |

The ratio $R/\sigma T_1^4$ which is given in column 6 of Table 6, shows variations with $e$ and also with the season of the year. The maximum values—which are in excess of 0.40—were obtained in March, with low values of $e$, but not the minimum values. The minimum values of the ratio, which are less than 0.20, were obtained with maximum values of $e$.

If we subtract the measured values of $R$ from $\sigma T_1^4$, the remainder gives the effective radiation from the atmosphere, $R_a = \sigma T_2^4$ from which $T_2$ may be computed. In column 7 of Table 6, $\Delta T$ is the difference $T_2 - T_1$. Following Ångström,[7] the values of $R_a$ have been

[7] *Ångström, A.* Op. cit., p. 42.

reduced to a uniform temperature of $T_1=293°$, by the equation

$$\frac{R_a}{R_{a20}}=\frac{T_1^4}{293^4}. \qquad (5)$$

The results are given in the last column of Table 6, and the mean values are plotted in figure 3, which also contains the mean values of $R_{20}$, or $R$ reduced to $T_1=293°$, as above.

If, after allowing for the different values of $\sigma$ employed by Ångström and myself, these plotted values of $R_{20}$ are compared with Ångström's Bassour measurements,[8] it will be found that the values corresponding to vapor pressures 1.82mm., 2.57mm., and 4.67mm., which are my maximum values, agree very closely with Ångström's curve. The remaining plotted values are lower than Ångström's, and the decrease in the value of $R_{20}$ with increase in surface vapor pressure is greater than Ångström found it to be. It will be noted that the value of $R_{20}$ corresponding to vapor pressure 1.54, which is based upon measurements all of which were made in December, 1914, are markedly lower than the mean curve.

This is probably due at least in part to the vertical temperature gradient of the atmosphere at the time. In early winter, and especially with abnormally low surface temperature, the vertical gradients of both temperature and vapor pressure are small as compared with spring and early summer.[9] In consequence the effective radiation of the sky will be low.

The low values of $R_{20}$ with high values of $e$ may be due to the fact that the atmosphere was nearly saturated, and clouds may have been forming, although not distinguishable at night.

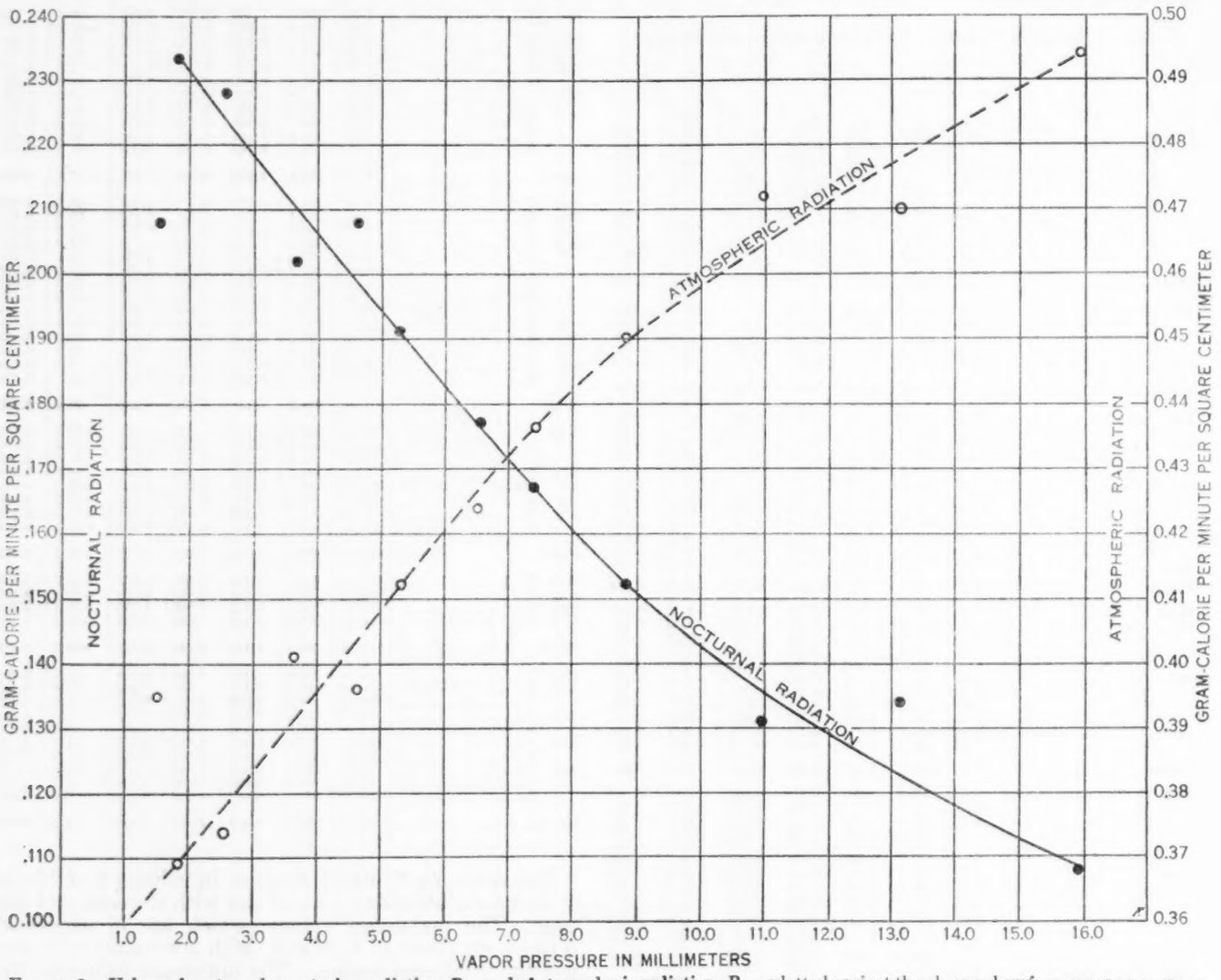


FIGURE 3.—Values of nocturnal or outgoing radiation, $R_{20}$, and of atmospheric radiation, $R_{a20}$, plotted against the observed surface vapor pressure, $e$.

It is also of interest to note that during the latter part of May and early June, 1914, when high values of $R$ were being measured, the atmosphere was filled with haze, or smoke from forest fires, so that solar radiation intensities were greatly reduced. Solar radiation intensities show that the atmosphere had cleared by June 16, but the values of $R$ were not increased.

[8] *Ångström, A.* Op. cit., p. 36, fig. 3.

[9] *Blair, Wm. R.* Summary of the free-air data obtained at Mount Weather for the five years July 1, 1907, to June 30, 1912. Bull. Mount Weather Observatory, 1913, 6:111-194.

From Tables 4 and 5 it will be seen that on May 18–19, May 19–20, June 2–3, and September 15–16, 1914, and on March 9–10, and March 12–13, 1915, the radiation was measured at frequent intervals throughout most of the night. The series of September 15–16 was interrupted by clouds. Those of May and June show little variation in $R$ throughout the night, except a pronounced drop just before sunrise. Those of March, 1915, show irregular variations, there being a pronounced decrease in the value of $R$ about midnight of March 9–10, and an increase followed by a decrease on the night of March 12–13.

Several series extending from 8 p. m. to 5 a. m. were obtained in North Carolina during May, 1915 (see Table 9), but there was more or less cloudiness on every night.

It is also evident from Table 4 that while haze has no appreciable effect upon the radiation to the atmosphere, and that cirrus clouds have only a slight effect, clouds in the alto-cumulus level and below diminished the radiation markedly. In fact, on June 9, 1914, the instrument appeared to be receiving more heat from low stratus clouds than it was radiating to them. Table 7 gives other low values of radiation to cloud layers.

TABLE 7.—*Radiation to clouds.*

[Gram-calories per minute per square centimeter.]

| Date. | R. | Clouds. |
|---|---|---|
| | *cal.* | |
| July 6 | 0.027 | 10/10 St. |
| Sept. 2 | 0.028 | 9/10 St.Cu. |
| Aug. 11 | 0.040 | 10/10 St.Cu. |
| July 7 | 0.043 | 10/10 St.Cu. |

## NOCTURNAL RADIATION MEASUREMENTS AT ELLIJAY, N. C.

During May, 1915, nocturnal radiation measurements were undertaken in North Carolina in connection with extensive frost studies that were being conducted there by Prof. H. J. Cox. Information was desired relative to the rate of radiation in the valleys, where frosts frequently occur, on the peaks, where the diurnal variations in temperature are small, and on the slopes, in the so-called thermal or frost-free belts.

Ellijay, N. C., was selected as the most favorable point for these measurements. On the north slope of Peak Knob (lat. 35° 11′ N., long. 83° 15′ W.) which rises abruptly from the narrow valley of Ellijay Creek, are located five Weather Bureau instrument shelters, each equipped with a maximum and a minimum thermometer and a thermograph. The elevations above sealevel, and the annual mean minimum temperatures at the different shelters, are shown in Table 8.

TABLE 8.—*Elevations above sealevel and annual mean minimum temperatures at Weather Bureau instrument shelters on Peak Knob, Macon County, N. C. (Lat. 35° 11′ N., long. 83° 15′ W.)*

| Shelters. | Elevations. | | Annual mean minimum temperatures. | |
|---|---|---|---|---|
| | *Feet.* | *meters.* | *°F.* | *°C.* |
| No. 1 | 2,240 | 683 | 41.2 | 5.1 |
| No. 2 | 2,550 | 777 | 42.4 | 5.8 |
| No. 3 | 2,860 | 872 | 44.3 | 6.8 |
| No. 4 | 3,480 | 1,061 | 45.7 | 7.6 |
| No. 5 | 4,000 | 1,219 | 44.8 | 7.1 |

Nocturnal radiation station **1**, was established beside instrument shelter 1, in the narrow valley of Ellijay Creek, and but a few yards from its bank. A tent kindly loaned for the purpose by the United States War Department was pitched beside the shelter, and in it were installed the galvanometer, the mil-ammeter, and other auxiliary apparatus, while the pyrgeometers were exposed on top of the instrument shelter. A similar installation, station **5**, was made beside shelter 5, which is on a shoulder just below the highest point on Peak Knob. Pyrgeometers Nos. $1_{bis}$, 2, and 3, were employed in making the measurements, two of the instruments being installed at station **1**. After a night on which satisfactory observations were obtained the instrument at station **5** was exchanged for one of the instruments at station **1**. In this way all the instruments were compared.

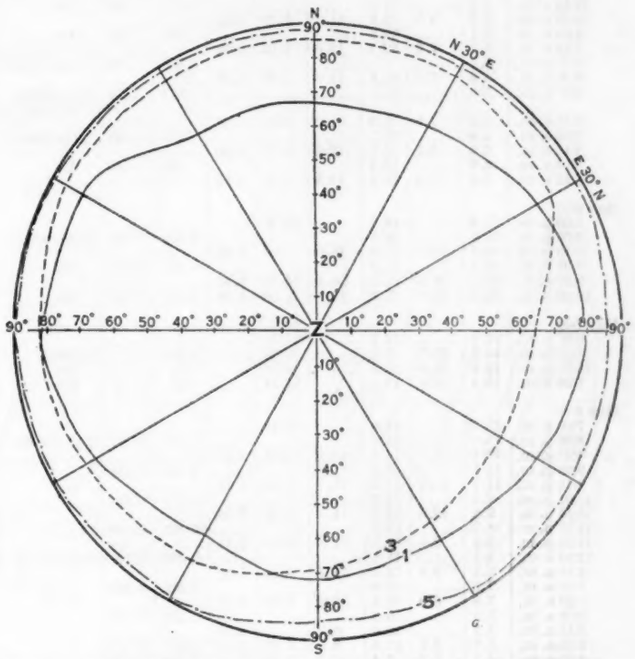


FIGURE 4.—Zenith distance of the sky line at radiation stations **1, 3,** and **5,** Ellijay, N. C.

At first 10 readings were made with each instrument as nearly as possible on the hour (75th mer. time) from 8 p. m. to 5 a. m. The readings at station **5** were so even, however, that the number in a series was soon reduced to five. At the end of each series a sling psychrometer was whirled near the instrument shelter to obtain the air temperature and the dew point.

Table 9 contains a summary of the readings obtained at these two stations between May 5 and May 10, 1915. There are also added temperature readings obtained from the traces made by the thermographs in the instrument shelters. The traces have been corrected by comparison with the readings of the maximum and the minimum thermometers in each shelter. The vapor pressure obtained from a psychrometer reading at sunset at station **3** is also added.

TABLE 9.—*Temperature, vapor pressure, and noctural radiation measurements at Ellijay, N. C., during May, 1915.*

| Date and time. | Temperature. | | | | Vapor pressure. | | Nocturnal radiation. | | Notes. |
|---|---|---|---|---|---|---|---|---|---|
| | Station No. 1. | | Station No. 5. | | Station No. 1. | Station No. 5. | Station No. 1. | Station No. 5. | |
| | Shelter. | Psychrometer. | Shelter. | Psychrometer. | | | | | |
| 1915. | | | | | | | | | |
| May 5–6: | °C. | °C. | °C. | °C. | mm. | mm. | cal. | cal. | |
| 7:00 p. m. | 15.0 | ..... | 16.1 | ..... | *6.76 | ..... | ..... | ..... | |
| 8:00 p. m. | 11.7 | ..... | 13.3 | ..... | ..... | ..... | ..... | ..... | 1/10 St.Cu. |
| 8:22 p. m. | 10.6 | ..... | 12.8 | ..... | ..... | ..... | 0.136 | 0.177 | Clear. |
| 8:30 p. m. | 10.0 | 13.4 | 12.8 | ..... | 7.04 | ..... | ..... | ..... | |
| 9:07 p. m. | 9.4 | ..... | 12.2 | ..... | ..... | ..... | .122 | .178 | Do. |
| 9:15 p. m. | 8.9 | 11.1 | 12.2 | 12.7 | 7.04 | 5.16 | ..... | ..... | |
| 10:02 p. m. | 7.8 | ..... | 12.2 | ..... | ..... | ..... | .117 | .169 | Do. |
| 10:10 p. m. | 7.8 | 9.6 | 12.2 | 12.1 | 7.29 | 4.95 | ..... | ..... | |
| 11:08 p. m. | 6.7 | ..... | 12.2 | ..... | ..... | ..... | .103 | .172 | Few clouds. |
| 11:15 p. m. | 6.7 | 8.5 | 12.2 | 12.4 | 7.04 | 5.16 | ..... | ..... | |
| 12:10 a. m. | 7.2 | ..... | 12.2 | ..... | ..... | ..... | 0.072 | .130 | Do. |
| 12:20 a. m. | 7.2 | 9.0 | 12.2 | 11.7 | 7.29 | 6.27 | ..... | ..... | |
| 1:05 a. m. | 6.1 | ..... | 12.2 | ..... | ..... | ..... | .096 | .149 | Do. |
| 1:15 a. m. | 6.1 | 7.8 | 12.2 | 12.0 | 7.04 | 5.21 | ..... | ..... | |
| 2:07 a. m. | 5.6 | ..... | ..... | ..... | ..... | ..... | .096 | .143 | Thin clouds. |
| 2:20 a. m. | 5.6 | 7.8 | 11.9 | 11.9 | 7.04 | 5.16 | ..... | ..... | |
| 3:07 a. m. | 5.6 | ..... | 11.9 | ..... | ..... | ..... | .074 | .136 | Increasing clouds. |
| 3:15 a. m. | 5.6 | 7.8 | 11.9 | 11.9 | 7.04 | 5.08 | ..... | ..... | |
| 4:05 a. m. | 4.4 | ..... | 12.2 | ..... | ..... | ..... | .092 | .135 | Thin clouds. |
| 4:15 a. m. | 4.4 | 6.7 | 12.2 | 12.3 | 6.76 | 5.16 | ..... | ..... | |
| 5:04 a. m. | 3.9 | ..... | 12.2 | ..... | ..... | ..... | .082 | .163 | Do. |
| 5:12 a. m. | 3.9 | 6.2 | 12.2 | 12.8 | 6.50 | 4.95 | ..... | ..... | |
| May 6–7: | | | | | | | | | |
| 7:00 p. m. | 17.8 | ..... | 16.7 | ..... | †9.80 | ..... | ..... | ..... | |
| 8:03 p. m. | 17.2 | ..... | 16.7 | ..... | ..... | ..... | 0.074 | 0.091 | 10/10 St.Cu. |
| 8:15 p. m. | 16.7 | 18.9 | 16.7 | 16.0 | 9.65 | 8.48 | ..... | ..... | |
| 9:08 p. m. | 19.4 | ..... | 17.2 | ..... | ..... | ..... | 0.035 | 0.046 | Do. |
| 9:20 p. m. | 20 0 | 19.2 | 17.2 | 16.8 | 10.77 | 8.48 | ..... | ..... | |
| 10:00 p. m. | 20.6 | 20.8 | 17.2 | 16.8 | 11.58 | 8.48 | 0.077 | 0.078 | Do. |
| May 7–8: | | | | | | | | | |
| 6:00 p. m. | 14.4 | ..... | 12.2 | ..... | *11.81 | ..... | ..... | ..... | |
| 8:15 p. m. | 13.9 | 15.3 | 12.2 | ..... | 12.04 | ..... | 0.010 | ..... | 10/10 St. |
| 10:05 p. m. | 13.9 | 15.6 | 12.2 | ..... | 12.24 | ..... | (‡) | ..... | Do. |
| 1:00 a. m. | 13.3 | 15.6 | 12.2 | ..... | 12.24 | ..... | (‡) | ..... | Do. |
| May 8–9: | | | | | | | | | |
| 7:00 p. m. | 15.6 | ..... | 15.0 | ..... | *8.48 | ..... | ..... | ..... | |
| 8:05 p. m. | 12.8 | ..... | 13.6 | ..... | ..... | ..... | 0.122 | 0.151 | 2/10 clouds. |
| 8:15 p. m. | 12.8 | 13.8 | 13.3 | 13.2 | 10.21 | 7.29 | ..... | ..... | |
| 9:05 p. m. | 11.1 | ..... | 12.2 | ..... | ..... | ..... | 0.122 | 0.158 | |
| 9:15 p. m. | 11.1 | 11.9 | 12.2 | 11.7 | 9.30 | 7.75 | ..... | ..... | |
| 10:07 p. m. | 9.4 | ..... | 12.2 | ..... | ..... | ..... | 0.115 | 0.168 | |
| 10:15 p. m. | 9.4 | 10.8 | 12.2 | 11.7 | 8.99 | 7.29 | ..... | ..... | |
| 11:10 p. m. | 8.9 | ..... | 11.7 | ..... | ..... | ..... | a0.111 | 0.166 | |
| 11:20 p. m. | 8.9 | 9.8 | 11.7 | 11.3 | 8.58 | 7.11 | ..... | ..... | |
| 12:10 a. m. | 8.3 | ..... | 11.1 | ..... | ..... | ..... | 0.096 | 0.149 | Few St. Cu. in N. to E. 12 p. m. to 3 a. m. |
| 12:15 a. m. | 8.3 | 9.4 | 11.1 | 10.7 | 8.36 | 7.39 | ..... | ..... | |
| 1:10 a. m. | 7.8 | ..... | 10.6 | ..... | ..... | ..... | 0.092 | 0.146 | |
| 1:20 a. m. | 7.8 | 8.9 | 10.6 | 10.2 | 8.00 | 6.76 | ..... | ..... | |
| 2:05 a. m. | 7.2 | ..... | 10.0 | ..... | ..... | ..... | 0.090 | 0.146 | |
| 2:15 a. m. | 7.2 | ..... | 10.0 | 9.2 | ..... | 6.76 | ..... | ..... | |
| 3:10 a. m. | 6.7 | 8.1 | 10.0 | 9.1 | 7.42 | 6.68 | 0.097 | 0.150 | |
| 4:05 a. m. | 6.1 | 7.7 | 9.4 | 8.3 | 7.42 | 6.68 | 0.080 | 0.152 | |
| 5:05 a. m. | 5.6 | 6.9 | 8.9 | 8.9 | 7.16 | 6.60 | 0.079 | 0.150 | |
| 8:30 a. m. | ..... | ..... | ..... | ..... | ..... | ..... | (b) | ..... | |
| May 9–10: | | | | | | | | | |
| 7:00 p. m. | 15.0 | ..... | 12.8 | ..... | *7.29 | ..... | ..... | ..... | |
| 8:05 p. m. | 11.1 | ..... | 11.7 | ..... | ..... | ..... | 0.123 | 0.145 | 1/10 St.Cu. |
| 8:15 p. m. | 11.1 | 11.7 | 11.7 | 11.3 | 9.14 | 6.76 | ..... | ..... | |
| 9:03 p. m. | 10.0 | ..... | 11.1 | ..... | ..... | ..... | c0.120 | 0.126 | Few St.Cu. |
| 9:10 p. m. | 10.0 | 10.6 | 10.6 | 10.2 | 8.64 | 7.37 | ..... | ..... | |
| 10:02 p. m. | 8.9 | ..... | 10.6 | ..... | ..... | ..... | 0.108 | 0.163 | Clear. |
| 10:10 p. m. | 8.9 | 9.7 | 10.6 | 11.2 | 8.18 | 7.09 | ..... | ..... | |
| 11:05 p. m. | 8.3 | ..... | 10.6 | ..... | ..... | ..... | c0.091 | 0.134 | Few St.Cu. |
| 11:10 p. m. | 8.3 | 9.2 | 10.6 | 10.1 | 7.87 | 6.98 | ..... | ..... | |
| 12:03 a. m. | 7.5 | 9.4 | ..... | ..... | ..... | ..... | 0.095 | 0.159 | Clear. |
| 12:10 a. m. | 7.5 | 8.2 | 10.0 | 9.7 | 7.62 | 6.27 | ..... | ..... | |
| 1:08 a. m. | 6.7 | ..... | 9.2 | ..... | ..... | ..... | 0.092 | 0.153 | Do. |
| 1:15 a. m. | 6.7 | 7.3 | 9.2 | 9.0 | 7.14 | 6.71 | ..... | ..... | |
| 2:00 a. m. | 5.8 | ..... | 8.3 | ..... | ..... | ..... | ..... | ..... | |
| 3:03 a. m. | 5.3 | ..... | 8.1 | ..... | ..... | ..... | 0.098 | 0.173 | Do. |
| 3:10 a. m. | 5.3 | 6.1 | 8.1 | 7.3 | 6.60 | 6.07 | ..... | ..... | |
| 4:00 a. m. | 4.4 | ..... | 8.1 | ..... | ..... | ..... | ..... | ..... | |
| 5:05 a. m. | 3.9 | ..... | 7.8 | ..... | ..... | ..... | 0.093 | 0.177 | Clear; light fog in valley. |
| 5:10 a. m. | 3.9 | 5.0 | 7.8 | 7.2 | 6.07 | 5.61 | ..... | ..... | Frost 1 mile up creek. |

* Station No. 3.
† Station No. 3. Rain began at 10:30 p. m.; ended at 6:40 p. m., 7th.
‡ Less than 0.009.

a Dew on case of instruments at Station 1.
b Dew on tinfoil of both instruments under covers of cases when latter was taken off at 8:30 a. m.
c Dew on instrument shelter.

| Date and time. | Temperature. | | | | Vapor pressure. | | Nocturnal radiation. | | Notes. |
|---|---|---|---|---|---|---|---|---|---|
| | Station No. 1. | | Station No. 3. | | Station No. 1. | Station No. 3. | Station No. 1. | Station No. 3. | |
| | Shelter. | Psychrometer. | Shelter. | Psychrometer. | | | | | |
| 1915. | | | | | | | | | |
| May 10–11: | °C. | °C. | °C. | °C. | mm. | mm. | cal. | cal. | |
| 7:00 p. m. | 18.9 | ..... | 16.7 | ..... | ..... | 8.48 | ..... | ..... | |
| 8:10 p. m. | 13.9 | ..... | 15.6 | ..... | ..... | ..... | 0.120 | 0.120 | 2/10 clouds. |
| 8:15 p. m. | 13.3 | 13.1 | 15.6 | 15.7 | 9.65 | 8.23 | ..... | ..... | |
| 9:05 p. m. | 11.7 | ..... | 15.3 | ..... | ..... | ..... | 0.101 | 0.108 | |
| 9:15 p. m. | 11.7 | 12.3 | 15.0 | 15.6 | 9.45 | 7.75 | ..... | ..... | |
| 10:05 p. m. | 11.1 | ..... | 14.4 | ..... | ..... | ..... | 0.094 | 0.111 | Few Ci.St. |
| 10:10 p. m. | 10.8 | 11.6 | 14.4 | 15.2 | 8.53 | 7.90 | ..... | ..... | |
| 11:10 p. m. | 10.0 | ..... | 13.9 | ..... | ..... | ..... | a0.084 | 0.105 | 2/10 Ci.St. |
| 11:15 p. m. | 10.0 | 11.4 | 13.9 | 13.7 | 8.89 | 7.77 | ..... | ..... | |
| 12:10 a. m. | 10.0 | ..... | 13.3 | ..... | ..... | ..... | 0.079 | 0.084 | 5/10 Ci.St. |
| 12:15 a. m. | 10.0 | 11.0 | 13.3 | 14.4 | 9.14 | 7.47 | ..... | ..... | |
| 1:02 a. m. | 9.7 | ..... | 12.8 | ..... | ..... | ..... | 0.072 | 0.082 | Cloudy but stars overhead. |
| 1:10 a. m. | 9.7 | 10.8 | 12.8 | 14.4 | 8.81 | 7.57 | ..... | ..... | |
| 2:00 a. m. | 9.4 | ..... | 12.8 | ..... | ..... | ..... | 0.066 | 0.095 | Sky nearly overcast with Ci.St. |
| 2:05 a. m. | 9.4 | 10.6 | 12.8 | 13.8 | 8.89 | 8.05 | ..... | ..... | |
| 3:05 a. m. | 9.2 | ..... | 12.8 | ..... | ..... | ..... | 0.044 | 0.083 | Cloudy, few stars visible. |
| 3:10 a. m. | 9.2 | 11.1 | 12.8 | 14.6 | 9.14 | 8.18 | ..... | ..... | |
| 4:07 a. m. | 9.4 | ..... | 12.8 | ..... | ..... | ..... | 0.051 | 0.083 | Cloudy, more stars visible. |
| 4:15 a. m. | 9.7 | 11.6 | 12.8 | 14.3 | 9.14 | 8.58 | ..... | ..... | |
| 5:10 a. m. | 10.3 | ..... | 13.3 | ..... | ..... | ..... | 0.060 | 0.080 | 10/10 St.Cu. |
| 5:15 a. m. | 10.6 | 12.8 | 13.3 | 14.1 | 9.83 | 9.04 | ..... | ..... | |
| May 12–13: | | | | | | | | | |
| 7:00 p. m. | 16.7 | ..... | 17.2 | ..... | ..... | 13.13 | ..... | ..... | |
| 8:08 p. m. | 13.3 | ..... | 14.4 | ..... | ..... | ..... | a0.099 | 0.114 | 2/10 St.Cu. |
| 8:15 p. m. | 13.3 | 13.8 | 14.4 | 14.9 | 10.92 | 11.30 | ..... | ..... | |
| 9:03 p. m. | 11.9 | ..... | 12.8 | ..... | ..... | ..... | 0.084 | 0.112 | 1/10 St.Cu. [illegible] in NW. |
| 9:10 p. m. | 11.9 | 13.3 | 12.8 | 13.9 | 10.97 | 10.97 | ..... | ..... | 9/10 St.Cu. |
| 10:05 p. m. | 12.2 | ..... | 13.1 | ..... | ..... | ..... | b0.033 | b0.052 | |
| 10:10 p. m. | 12.2 | 13.4 | 13.1 | 14.0 | 11.25 | 10.67 | ..... | ..... | |
| 11:10 p. m. | 11.9 | ..... | 12.8 | ..... | ..... | ..... | 0.045 | 0.056 | 8/10 St.Cu. |
| 11:15 p. m. | 11.9 | 13.1 | 12.8 | 14.3 | 11.23 | 10.90 | ..... | ..... | |
| 12:15 a. m. | 11.7 | ..... | 12.8 | ..... | ..... | ..... | 0.064 | 0.091 | 1/10 St.Cu. |
| 12:20 a. m. | 11.1 | 12.8 | 12.2 | 12.9 | 10.21 | 10.16 | ..... | ..... | |
| 1:05 a. m. | 10.6 | ..... | 11.7 | ..... | ..... | ..... | 0.069 | 0.088 | Few clouds. |
| 1:10 a. m. | 10.6 | 11.8 | 11.7 | 13.2 | 10.03 | 10.44 | ..... | ..... | |
| 2:04 a. m. | 10.6 | ..... | 11.7 | ..... | ..... | ..... | 0.048 | 0.058 | 5/10 Ci. St. |
| 2:10 a. m. | 10.6 | 11.8 | 11.7 | 13.8 | 10.11 | 10.90 | ..... | ..... | |
| 3:03 a. m. | 10.6 | ..... | 11.7 | ..... | ..... | ..... | 0.052 | 0.054 | Stars brighter. |
| 3:10 a. m. | 10.6 | 11.7 | 11.7 | 13.3 | 10.11 | 10.46 | ..... | ..... | |
| 4:05 a. m. | 10.0 | ..... | 11.1 | ..... | ..... | ..... | 0.021 | 0.026 | More clouds. |
| 4:10 a. m. | 10.0 | 11.7 | 11.1 | 12.5 | 10.06 | 9.83 | ..... | ..... | |
| 5:08 a. m. | 9.4 | ..... | 11.1 | ..... | ..... | ..... | 0.034 | 0.045 | (c) |
| 5:15 a. m. | 9.4 | 11.0 | 11.1 | 12.1 | 9.35 | 10.16 | ..... | ..... | |
| May 13–14: | | | | | | | | | |
| 7:00 p. m. | 18.3 | ..... | 20.6 | ..... | ..... | 10.59 | ..... | ..... | |
| 8:10 p. m. | 14.4 | ..... | 18.3 | ..... | ..... | ..... | 0.104 | 0.132 | Few Ci. |
| 8:15 p. m. | 14.4 | 15.6 | 18.3 | 19.3 | 11.81 | 10.87 | ..... | ..... | |
| 9:15 p. m. | 13.3 | 14.9 | 16.7 | 17.8 | 11.23 | 10.01 | ..... | ..... | |
| 10:02 p. m. | 11.9 | ..... | 15.0 | ..... | ..... | ..... | a0.089 | 0.129 | Clear. |
| 10:10 p. m. | 11.9 | 13.7 | 15.0 | 16.6 | 10.82 | 10.46 | ..... | ..... | |
| 11:01 p. m. | 11.7 | ..... | 14.4 | ..... | ..... | ..... | 0.079 | 0.104 | Few clouds. |
| 11:07 p. m. | 11.4 | 13.3 | 14.4 | 15.2 | 10.67 | 10.41 | ..... | ..... | |
| 12:03 a. m. | 10.8 | ..... | 13.9 | ..... | ..... | ..... | b0.082 | 0.129 | Clear. |
| 12:10 a. m. | 10.8 | 12.8 | 13.9 | 15.7 | 10.16 | 9.98 | ..... | ..... | |
| 1:03 a. m. | 10.3 | ..... | 13.3 | ..... | ..... | ..... | a0.083 | 0.116 | Do. |
| 1:10 a. m. | 10.3 | 12.1 | 13.3 | 14.1 | 9.91 | 10.26 | ..... | ..... | |
| 2:15 a. m. | 10.0 | ..... | 12.8 | ..... | ..... | ..... | 0.070 | 0.117 | Clear. |
| 2:20 a. m. | 10.0 | 11.5 | 12.8 | 13.8 | 9.75 | 9.98 | ..... | ..... | |
| 3:05 a. m. | 9.4 | ..... | 12.2 | ..... | ..... | ..... | 0.073 | d0.122 | Do. |
| 3:10 a. m. | 9.4 | 11.1 | 12.2 | 13.2 | 9.22 | 10.06 | ..... | ..... | |
| 4:01 a. m. | 8.9 | ..... | 12.2 | ..... | ..... | ..... | 0.071 | d0.124 | Do. |
| 4:05 a. m. | 8.9 | 10.6 | 12.2 | 12.9 | 9.04 | 9.96 | ..... | ..... | |
| 5:02 a. m. | 8.9 | 10.3 | 11.7 | 12.9 | 9.02 | 9.80 | 0.081 | 0.122 | Do. |
| 5:05 a. m. | 8.9 | 10.3 | 11.7 | 12.9 | 9.02 | 9.80 | ..... | ..... | Few Ci., light fog in valley. |
| May 14–15: | | | | | | | | | |
| 7:00 p. m. | 19.4 | ..... | 20.0 | ..... | ..... | 13.61 | ..... | ..... | |
| 8:07 p. m. | 16.7 | ..... | 18.9 | ..... | ..... | ..... | 0.083 | 0.126 | Few Ci. |
| 8:15 p. m. | 16.1 | 17.1 | 18.9 | 19.4 | 13.46 | 12.24 | ..... | ..... | |
| 9:07 p. m. | 14.4 | ..... | 17.2 | ..... | ..... | ..... | a0.091 | 0.126 | Clear. |
| 9:12 p. m. | 14.4 | 15.6 | 17.2 | 18.3 | 12.24 | 11.38 | ..... | ..... | |
| 10:00 p. m. | 13.3 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | |
| 11:05 p. m. | 12.8 | ..... | 17.2 | ..... | ..... | ..... | b0.078 | b0.123 | Do. |
| 11:10 p. m. | 12.8 | 13.6 | 17.2 | 17.1 | 10.97 | 11.74 | ..... | ..... | |
| Midnight. | 12.2 | ..... | 17.8 | ..... | ..... | ..... | ..... | ..... | |
| 1:05 a. m. | 11.7 | ..... | 15.6 | ..... | ..... | ..... | 0.078 | 0.112 | Do. |
| 1:10 a. m. | 11.7 | 12.8 | 15.6 | 16.1 | 10.36 | 10.74 | ..... | ..... | |
| 2:00 a. m. | 11.4 | ..... | 15.6 | ..... | ..... | ..... | ..... | ..... | |
| 3:00 a. m. | 10.6 | ..... | 15.3 | ..... | ..... | ..... | 0.062 | 0.112 | Do. |
| 3:05 a. m. | 10.6 | 11.9 | 15.3 | 16.3 | 10.11 | 10.90 | ..... | ..... | |
| 4:00 a. m. | 10.0 | ..... | 15.0 | ..... | ..... | ..... | ..... | ..... | |
| 5:01 a. m. | 10.0 | ..... | 14.4 | ..... | ..... | ..... | 0.071 | 0.114 | Few St.Cu., lt. fog in valley. |
| 5:05 a. m. | 10.0 | 11.1 | 14.4 | 14.7 | 9.40 | 11.12 | ..... | ..... | |

a Dew on shelter at No. 1.
b Dew on shelter and instruments.
c Few clouds, fog all about, but not at stations Nos. 1 and 3.
d Top of shelter at No. 3, damp.

On May 10 the equipment at station 5 was moved to a similar installation beside shelter No. 3, where readings were made until May 15. These also are summarized in Table 9.

With reference to the nocturnal radiation measurements it is to be noted that those obtained at station 1 are markedly lower than synchronous measurements obtained at station 5 and somewhat lower than synchronous measurements obtained at station 3. The following are some of the reasons why this should be so:

(1) As shown in figure 4, the sky line at station 1 averages about 20° above the true horizon. At station 3, between east and south it is about 25° above, and in other directions it is generally from 5° to 10° above. At station 5 the sky line is but little above the true horizon in any direction. From Ångström's determinations[10] of the radiation from a horizontal surface to different parts of the sky, the elevation of the sky line at station 5 does not have an appreciable effect on the radiation. At station 1 it reduces the radiation by about one-thirtieth, and at station 3 it reduces it by a somewhat less amount.

(2) With clear skies the thermometers in the instrument shelters at stations 1 and 3 systematically read lower than the dry-bulb thermometer of the sling psychrometer which was whirled near the shelter. As shown in Table 9, the depression in shelter 1 frequently amounted to more than 2 degrees C. and was to a temperature below that of the dewpoint determined from the sling psychrometer readings. That the temperature of the top of this instrument shelter was below the dewpoint temperature of the air was shown by a copious deposit of dew upon it, as is indicated by the notes in Table 9. These notes state that dew formed on the top

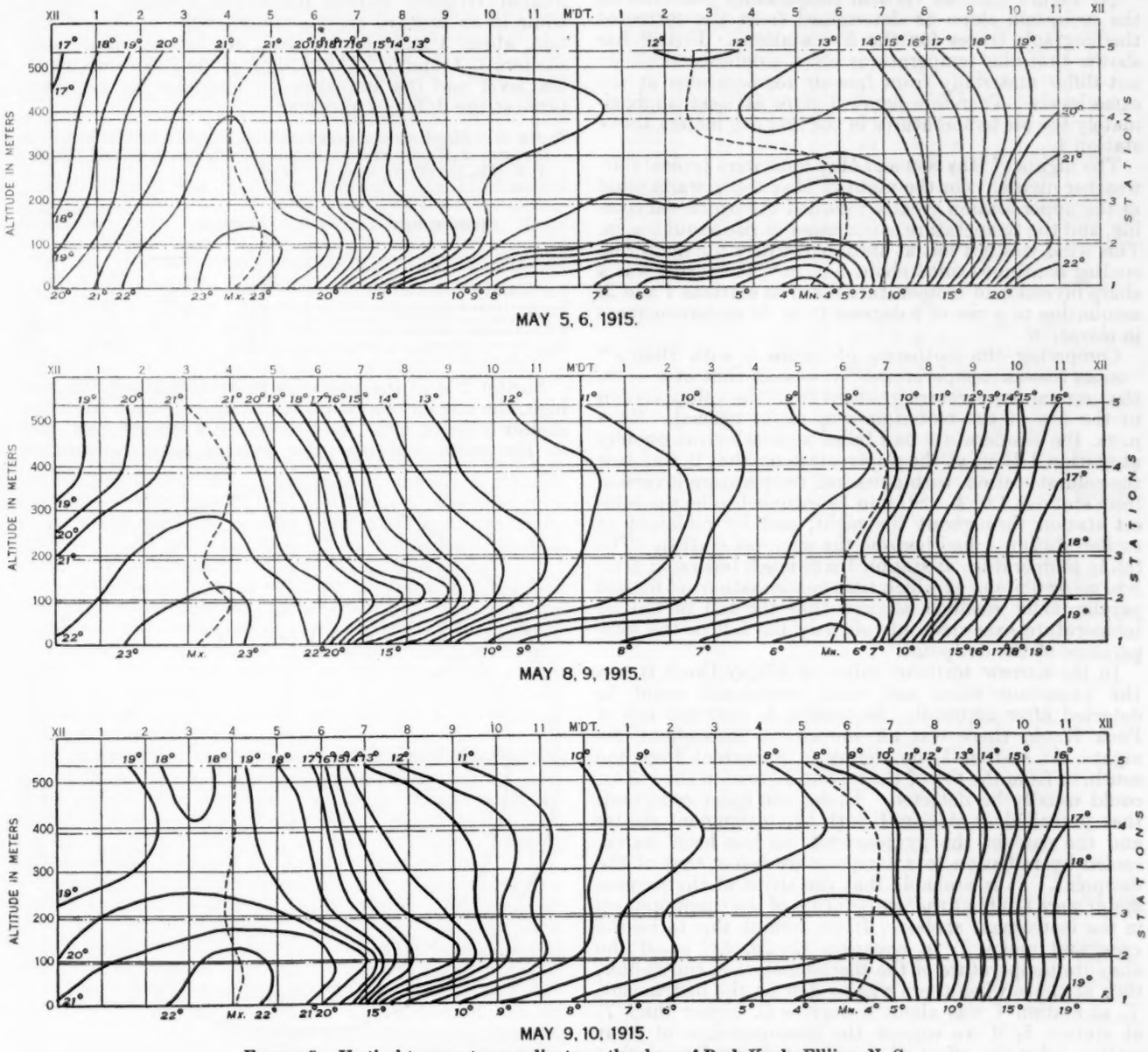


FIGURE 5.—Vertical temperature gradients on the slope of Peak Knob, Ellijay, N. C.

[10] Op. cit., p. 67, fig. 12.

of the shelter and on the cases of the instruments before midnight on nearly every clear night. On a few nights dew formed on both the shelter and the instrument at section 3, but it was not observed at station 5. While not actually observed, it is probable that when dew formed on the cases of the instruments it also formed on the radiating strips. The latent heat of condensation thus liberated neutralizes to some extent the cooling by radiation. Probably, also, the emissivity of the strips when wet is less than when dry.

(3) Figure 5 shows vertical temperature gradients on the mountain slope as determined from the corrected thermograph traces for the five stations. Blair [11] has shown that the temperatures on a mountain slope do not differ materially from free-air temperatures at the same levels. Therefore figure 5 gives at least approximately the air temperatures in the first 536 meters above station 1.

The nights of May 8–9 and May 9–10 were typical fair-weather nights. On the night of May 5–6 a warm wind at the upper station greatly retarded the nocturnal cooling, and the temperature commenced to rise about 2 a. m. This wind was not felt at station 1, where the nocturnal cooling continued until about 5 a. m. The result was a sharp inversion of temperature between stations 1 and 2, amounting to a rise of 5 degrees C. in 92 meters increase in elevation.

Comparing the isotherms of figure 5 with Blair's [12] "mean free-air temperatures," it is seen that at 4 p. m. the vertical temperature gradient from the valley station to the top of the mountain was about normal. By 8 p. m. the temperature had fallen so much more rapidly at station 1 than at the upper stations that it was now the coldest station, with a marked temperature inversion from stations 1 to 2. Station 1 continued to be the coldest station throughout the night, and by midnight or earlier station 4 had become the warmest station. The fall in temperature at station 1 was much less rapid after 8 p. m. or 9 p. m., at which time condensation set in, and psychrometer readings showed that the fall in the air temperature exceeded only slightly the fall in the temperature of the dewpoint.

In the narrow tortuous valley of Ellijay Creek it was the exception when any wind movement could be detected after nightfall. At station 5, near the top of Peak Knob, there was air movement throughout the night. At station 3, on the slope, a current from the south, or from the top of the mountain toward the valley, could usually be detected. Under the quiet conditions that prevailed at station 1 both the instrument shelter and the case of the pyrgeometer, as has been stated, cooled by radiation to a temperature below that of the dewpoint. It is probable that the strips of the pyrgeometer were at about the temperature of the thermometers in the instrument shelter. If we assume this to be the case, and make $T_1$ in equation (2) [p. 59] equal the absolute temperature of the thermometers in the shelter, then at times when there was no dew on the instrument, $T_2$ at station 1 was about 4 degrees C. higher than $T_2$ at station 5, if we correct the measurements of $R$ at station 1 for the effect of the elevated sky line at that station.

[11] *Blair, Wm. R.* Summary of the free-air data obtained at Mount Weather for the five years July 1, 1907, to June 30, 1912. Bull., Mount Weather Obs., Washington, 1914, 6:118–124. (See section on mountain and valley temperatures.)

[12] *Blair, Wm. R.* Op. cit., p. 179, fig. 1.

The values of $T_2$ for station 3 do not differ materially from the values at station 1. It therefore appears that there is some effect, probably due to the elevated sky line of the valley and slope stations, that has not been entirely eliminated.

### NOCTURNAL RADIATION MEASUREMENTS AT HIGHLANDS, N. C.

In an orchard on the south slope of Satulah Mountain, Highlands, N. C. (lat. 35° 02′ N., long. 83° 13′ W.), are located Weather Bureau instrument shelters 1 and 2, while in an orchard on the eastern slope of Dog Mountain, about 3 miles to the west, are located instrument shelters 3, 4, and 5. Table 10 gives the elevations above sea level and the annual mean minimum air temperatures at the different shelters.

TABLE 10.—*Elevations above sea level and annual mean minimum temperatures at Weather Bureau stations at Highlands, Macon County, N. C. (lat. 35° 02′ N., long. 83° 13′ W.)*

| Shelter number. | Elevations. | | Annual mean minimum temperatures. | |
|---|---|---|---|---|
| | *Feet.* | *meters.* | *°F.* | *°C.* |
| 1 | 3,350 | 1,021 | 44.7 | 7.1 |
| 2 | 3,550 | 1,082 | 46.1 | 7.8 |
| 3 | 3,675 | 1,120 | 37.1 | 2.8 |
| 4 | 3,875 | 1,181 | 42.2 | 5.7 |
| 5 | 4,075 | 1,242 | 43.3 | 6.3 |

Shelter 2 is at the base of a rocky cliff about 800 feet high, the angular elevation of the top of which from the shelter is about 42°. To the west is a dense forest, and to the south and east the orchard slopes downward

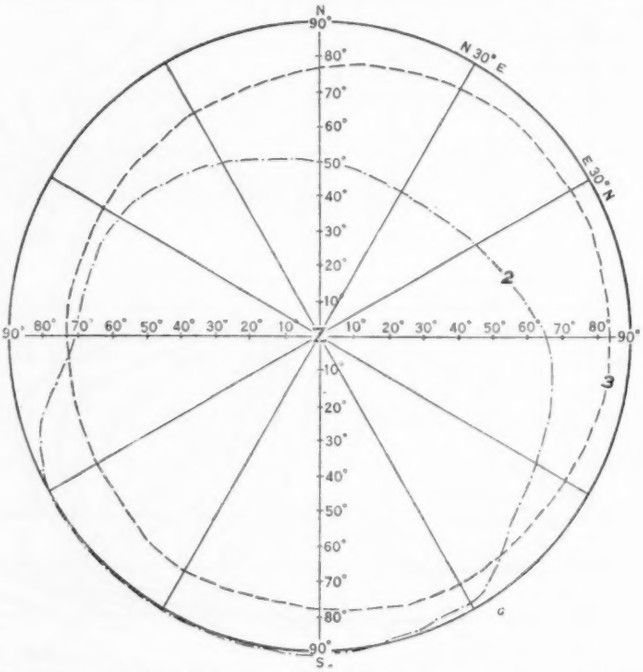


FIGURE 6.—Zenith distance of the sky line at radiation stations No. 2 and No. 3, Highlands, N. C.

toward Clear Creek Valley. The location of the shelter is such that it can receive radiation from the sun during almost the entire day, but at night nocturnal radiation is retarded by the cliffs and the forest trees.

Shelter 3 is on the edge of Buttermilk Level, a much broader mountain valley than that at Ellijay. It has the local reputation of being the coldest place in that part of the mountains.

Figure 6 shows the elevation of the sky line above the true horizon at shelters 2 and 3. From Ångström's diagrams [13] it does not appear that this should decrease the nocturnal radiation at station 3 by more than 2 per cent, but at 2 it may reduce such radiation by as much as 10 per cent. This would nearly equalize the readings at the two stations on the evening of May 17 (given in Table 11), which are the only reliable readings obtained at Highlands. The wind blew throughout the night of May 17–18, and light dew formed on the grass only, at station 3. On other nights the sky was less clear, there was little or no wind, and at station 3 there was a copious deposit of dew on the top of the instrument shelter and on the case of the pyrgeometer before midnight. Moisture globules were also observed on the radiating strips.

The value of $R_{a20}$ for the evening of May 17 is about 5 per cent higher than Ångström's values for corresponding vapor pressures, and somewhat higher than those for station 5, Ellijay, N. C.

While the diurnal cooling at station 3 caused an inversion of temperature above that station it was not so marked as at Ellijay. It was of the same general character, however, and doubtless is to be attributed to the same cause, namely, continued surface cooling in a confined valley where there was little opportunity for mixing with warmer air, as is the case on the slopes.

### RELATION BETWEEN RADIATION AND AIR TEMPERATURE.

The temperature of the air is very closely related to the temperature of the ground, which, in turn, is dependent upon the amount of heat received and absorbed during the day, and the rate at which heat is continuously given out. Of the heat received on a horizontal ground surface probably about 85 per cent is absorbed.

At Washington, during January, the mean daily surface temperature changes but little from day to day. The heat absorbed during the day must therefore about equal the losses from all sources. The average daily incoming radiation per square centimeter during this month is about 170 gram-calories, of which about 145 calories will be absorbed, or 0.10 calory per minute if distributed throughout the 24 hours.

At this season of the year with a clear sky the nocturnal radiation averages about 0.16 gram-calory per minute. If we assume that throughout the 24 hours and under all sorts of weather conditions the loss is 60 per cent of that measured by the instrument on clear nights, the outgoing radiation just balances the incoming radiation.

From the end of January to the end of June there is a steady increase in surface temperatures. During July they are nearly stationary again. At this time each square centimeter of surface receives on an average about 500 gram-calories of heat each day, and absorbs about 425 gram-calories, or 0.30 gram-calory per minute if distributed throughout 24 hours. The measured loss on clear nights is only about 0.20 gram-calory per minute. Consequently, at least half the heat received during the day must be carried away by convection, or expended in evaporation and other processes. By the end of October, when the incoming absorbed radiation has fallen to 225 gram-calories per day, or about 0.15 gram-calory per minute, it is noticeable that vertical convection has nearly ceased, as is shown by the absence of cumulus clouds.

[13] *Ångström, A.* Op. cit., page 67, figure 12.

TABLE II.—*Temperature, vapor pressure, and nocturnals radiation measurements at Highlands, N. C., during May, 1915.*

| Date and time. | Temperature. | | | | Vapor pressure. | | Nocturnal radiation. | | Notes. |
|---|---|---|---|---|---|---|---|---|---|
| | Station No. 2. | | Station No. 3. | | | | | | |
| | Shelter. | Psychrometer. | Shelter. | Psychrometer. | Station No. 2. | Station No. 3. | Station No. 2. | Station No. 3. | |
| May 17–18. | °C. | °C. | °C. | °C. | mm. | mm. | cal. | cal. | |
| 7:00 p. m. | 16.1 | ..... | 13.3 | ..... | *9.47 | ..... | ..... | ..... | |
| 8:10 p. m. | 13.9 | ..... | 12.2 | ..... | ..... | ..... | 0.127 | 0.158 | Clear. |
| 8:25 p. m. | 13.9 | 13.9 | 12.2 | 13.5 | 10.59 | 7.29 | ..... | ..... | |
| 9:05 p. m. | 12.8 | ..... | 11.1 | ..... | ..... | ..... | 0.133 | 0.151 | Do. |
| 9:10 p. m. | 12.8 | 13.1 | 11.1 | 12.5 | 8.33 | 7.42 | ..... | ..... | |
| 10:10 p. m. | 12.2 | ..... | 9.4 | ..... | ..... | ..... | 0.128 | 0.150 | Do. |
| 10:20 p. m. | 12.2 | 12.5 | 8.9 | 10.7 | 8.03 | 6.50 | ..... | ..... | |
| 11:02 p. m. | 10.6 | ..... | 8.9 | ..... | ..... | ..... | 0.122 | 0.136 | Do. |
| 11:10 p. m. | 10.6 | 11.1 | 8.9 | 8.9 | 8.00 | 6.76 | ..... | ..... | |
| 12:05 a. m. | 11.7 | ..... | 8.3 | ..... | ..... | ..... | 0.126 | 0.138 | Do. |
| 12:10 a. m. | 11.7 | 12.8 | 8.3 | 9.1 | 7.29 | 6.83 | ..... | ..... | |
| 1:10 a. m. | 12.2 | ..... | 8.3 | ..... | ..... | ..... | 0.123 | [a]0.127 | Do. |
| 1:15 a. m. | 12.2 | 12.8 | 8.3 | 10.4 | 7.39 | 7.07 | ..... | ..... | |
| 2:10 a. m. | 12.2 | ..... | 6.1 | ..... | ..... | ..... | 0.109 | 0.111 | Do. |
| 2:15 a. m. | 12.2 | 12.5 | 6.1 | 6.8 | 7.16 | 7.11 | ..... | ..... | |
| 3:10 a. m. | 12.8 | ..... | 5.6 | ..... | ..... | ..... | 0.041 | 0.069 | 5/10 Cu.St. |
| 3:30 a. m. | 12.8 | 13.3 | 5.6 | 5.9 | 6.50 | 6.58 | ..... | ..... | Few A. Cu. |
| 4:02 a. m. | 11.9 | ..... | 4.4 | ..... | ..... | ..... | 0.112 | 0.074 | |
| 4:10 a. m. | 11.9 | 12.9 | 4.4 | 4.9 | 6.81 | 6.17 | ..... | ..... | 5/10 A. Cu. |
| 5:02 a. m. | 11.7 | ..... | 4.4 | ..... | ..... | ..... | 0.079 | [d]0.012 | |
| 5:05 a. m. | 11.7 | 12.8 | 4.4 | 6.1 | 6.78 | 6.60 | ..... | ..... | |
| 6:05–6:30 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Lt. rain. |
| May 18–19. | | | | | | | | | |
| 7:00 p. m. | 17.8 | ..... | 17.2 | ..... | *10.21 | ..... | ..... | ..... | |
| 8:04 p. m. | 17.2 | ..... | 13.9 | ..... | ..... | ..... | 0.105 | 0.086 | |
| 8:10 p. m. | 17.2 | 18.2 | 13.9 | 13.8 | 11.38 | 10.14 | ..... | ..... | 6/10 St. Cu. |
| 9:10 p. m. | 15.6 | ..... | 11.7 | ..... | ..... | ..... | 0.113 | [a]0.094 | Clear. |
| 9:15 p. m. | 15.6 | 17.2 | 11.7 | 11.9 | 11.12 | 9.55 | ..... | ..... | |
| 10:04 p. m. | 15.6 | ..... | 10.6 | ..... | ..... | ..... | 0.108 | [b]0.074 | Few Ci. |
| 10:10 p. m. | 15.6 | 16.7 | 10.6 | 10.9 | 10.67 | 9.37 | ..... | ..... | |
| 11:00 p. m. | 16.1 | ..... | 9.4 | ..... | ..... | ..... | 0.117 | 0.058 | Few St. Cu. |
| 11:05 p. m. | 16.1 | 16.8 | 9.4 | 9.6 | 11.43 | 8.56 | ..... | ..... | |
| 12:10 a. m. | 16.1 | ..... | 8.9 | 8.9 | ..... | 8.18 | 0.098 | [c]0.036 | |
| 12:20 a. m. | 16.1 | 16.9 | 8.9 | ..... | 10.77 | ..... | ..... | ..... | |
| 1:04 a. m. | 16.1 | ..... | 8.3 | 8.7 | ..... | 8.31 | 0.087 | (e) | 3/10 Ci. |
| 1:10 a. m. | 16.1 | 16.9 | 8.3 | ..... | 11.38 | ..... | ..... | ..... | 1/10 A. Cu. |
| 2:10 a. m. | 16.1 | ..... | 8.3 | ..... | ..... | ..... | 0.100 | ..... | |
| 2:15 a. m. | 16.1 | 17.3 | 8.3 | ..... | 11.56 | ..... | ..... | ..... | 5/10 A. St. |
| 3:00 a. m. | 15.6 | ..... | 8.3 | 9.2 | ..... | 8.38 | ..... | ..... | |
| 3:08 a. m. | 15.6 | 17.2 | 8.3 | ..... | 11.81 | ..... | ..... | (f) | |
| May 21: | | | | | | | | | |
| 7:00 p. m. | 17.8 | ..... | 15.6 | ..... | *10.97 | ..... | ..... | ..... | |
| 8:10 p. m. | 17.2 | ..... | 14.4 | 14.4 | ..... | 11.46 | 0.088 | 0.086 | |
| 8:15 p. m. | 17.2 | 17.5 | 14.4 | ..... | 12.24 | ..... | ..... | ..... | 9/10 St. Cu. |
| 9:05 p. m. | 16.7 | 17.2 | 13.3 | 13.3 | 11.81 | 10.72 | 0.065 | 0.050 | 5/10 St. Cu. |
| 10:00 p. m. | 17.2 | ..... | 12.2 | 11.7 | ..... | 10.44 | ..... | [b]0.024 | |
| 11:00 p. m. | 17.2 | 17.2 | 11.7 | 11.7 | 12.50 | 9.83 | 0.059 | [b]0.049 | 6/10 St. Cu. |
| May 22–23: | | | | | | | | | |
| 7:00 p. m. | 16.7 | ..... | 17.2 | ..... | *13.61 | ..... | ..... | ..... | |
| 8:05 p. m. | 16.7 | ..... | 15.0 | ..... | ..... | ..... | ..... | ..... | Few clouds. |
| 8:10 p. m. | 16.7 | 17.0 | 15.0 | 14.6 | 13.41 | 11.51 | 0.091 | [g]0.093 | |
| 9:10 p. m. | 16.7 | ..... | 13.3 | 13.1 | ..... | 10.90 | ..... | ..... | Few Ci. |
| 9:15 p. m. | 16.7 | 16.7 | 13.3 | ..... | 12.78 | ..... | [b]0.088 | [b]0.052 | |
| 10:10 p. m. | 16.1 | ..... | 12.2 | ..... | ..... | ..... | ..... | ..... | |
| 10:15 p. m. | 16.1 | 15.7 | 12.2 | 12.1 | 12.37 | 10.36 | 0.091 | [g]0.050 | Lt. fog. |
| 11:00 p. m. | 15.6 | ..... | 12.2 | ..... | ..... | ..... | ..... | ..... | |
| 11:05 p. m. | 15.6 | 15.4 | 12.2 | 12.9 | 11.81 | 10.82 | [c]0.080 | 0.054 | |
| 12:15 a. m. | 15.6 | ..... | 11.1 | ..... | ..... | ..... | ..... | ..... | |
| 12:20 a. m. | 15.6 | 15.7 | 11.1 | 11.3 | 12.37 | 9.83 | 0.078 | 0.054 | Lt. fog. |
| 1:05 a. m. | 15.6 | ..... | 10.0 | ..... | ..... | ..... | ..... | ..... | |
| 1:15 a. m. | 15.6 | 15.6 | 10.0 | 10.1 | 12.24 | 9.07 | 0.085 | 0.030 | |
| 2:15 a. m. | 15.0 | ..... | 9.4 | ..... | ..... | ..... | ..... | ..... | |
| 2:25 a. m. | 15.0 | 15.4 | 9.4 | ..... | 12.04 | ..... | [g]0.084 | ..... | |
| 3:03 a. m. | 14.4 | ..... | 8.3 | ..... | ..... | ..... | ..... | ..... | |
| 3:10 a. m. | 14.4 | 15.0 | 8.3 | 9.0 | 11.81 | 8.31 | 0.074 | 0.030 | |
| 4:15 a. m. | 14.4 | ..... | 8.3 | ..... | ..... | ..... | ..... | ..... | |
| 4:30 a. m. | 14.4 | 14.4 | 8.3 | ..... | 11.30 | ..... | 0.096 | ..... | |
| 5:07 a. m. | 15.0 | ..... | 7.2 | ..... | ..... | ..... | ..... | ..... | |
| 5:15 a. m. | 15.0 | 15.0 | 7.2 | 8.0 | 11.23 | 7.87 | 0.091 | [h]0.031 | 10/10 Cl.St. & St. Cu. |
| May 23–24: | | | | | | | | | |
| 7:00 p. m. | 20.0 | ..... | 20.0 | ..... | *15.65 | ..... | ..... | ..... | |
| 8:00 p. m. | 17.8 | ..... | 18.3 | ..... | ..... | ..... | ..... | ..... | Rain, [f] |
| 9:05 p. m. | 17.8 | 18.1 | 16.7 | ..... | 14.60 | ..... | 0.043 | 0.056 | 6/10 St. Cu. |
| 9:10 p. m. | 17.8 | ..... | 16.7 | 15.1 | ..... | 12.42 | ..... | ..... | |
| 10:05 p. m. | 17.8 | 17.8 | 15.0 | ..... | 14.10 | 11.76 | 0.087 | 0.068 | 2/10 St. Cu. |
| 10:10 p. m. | 17.8 | ..... | 15.0 | 14.3 | ..... | ..... | ..... | ..... | |
| 10:57 p. m. | 17.2 | ..... | 14.4 | ..... | ..... | ..... | 0.075 | [c]0.076 | |
| 11:00 p. m. | 17.2 | 16.9 | 14.4 | 16.0 | 13.87 | 13.03 | ..... | ..... | 2/10 St. Cu. |
| 12:04 a. m. | 16.1 | ..... | 15.0 | ..... | ..... | ..... | 0.094 | ..... | |
| 12:15 a. m. | 16.1 | 16.2 | 15.0 | ..... | 12.80 | ..... | ..... | ..... | |
| 1:02 a. m. | 15.6 | ..... | 13.9 | ..... | ..... | ..... | 0.054 | 0.042 | 2/10 clouds. |
| 1:07 a. m. | 15.6 | 15.3 | 13.9 | 13.4 | 12.04 | 10.97 | ..... | ..... | |
| 3:02 a. m. | 15.0 | ..... | 11.7 | ..... | ..... | ..... | 0.091 | 0.054 | |
| 3:10 a. m. | 15.0 | 15.3 | 11.7 | 11.0 | 11.76 | 9.35 | ..... | ..... | |
| 5:00 a. m. | 16.1 | ..... | 8.9 | ..... | ..... | ..... | 0.068 | 0.034 | 7/10 St. Cu. |
| 5:05 a. m. | 16.1 | 16.1 | 8.9 | 9.3 | 13.13 | 8.56 | ..... | ..... | Fog in valley. |

* Station No. 1.
[a] Dew on grass.
[b] Dew on instrument shelter.
[c] Dew on case of pyrgeometer.
[d] Dew on instrument shelter and case of pyrgeometer.
[e] Less than 0.010.
[f] Rain began 4:45 a. m.; ended before 6:20 a. m.
[g] Dew evaporated from case of pyrgeometer.
[h] Small globules of water on black strips; outside of the pyrgeometer case dripping wet.

Reference to Blair's mean free-air temperatures [14] shows that the vertical temperature gradient is steeper during the spring than during the fall. In May, for example, the fall in temperature in 5 kilometers is 32 degrees (C.); in September it is 26 degrees. In conformity with the above in the spring nocturnal radiation is greater than in the fall, the intensity of solar radiation is a little greater, and so is the diurnal range of temperature.

Temperature inversions like those shown in figure 5, are not rare. They may occur on a plain where there is no wind movement to carry away the lower cooled air layer and mix it with warmer air. They are to be expected in deep valleys unless the valley grade is such that the cold air will flow out rapidly. The so-called thermal belts, or belts on the slopes that are free from injurious frosts at critical times, are due to the fact that as soon as the surface air layer on the slope becomes cooled there is a convective exchange between it and warmer adjacent air that may have been on the same level, but was farther removed from the slope surface.[15]

On the slope of Peak Knob frosts injurious to fruit are unknown between the 200-meters and the 400-meters levels, while fruit can not be raised in the valley at the foot of the slope.

I wish to acknowledge my indebtedness to Dr. (now Maj.) William R. Blair for valuable suggestions and assistance in connection with the test of pyrgeometer No. 1 at Mount Weather, Va.; to Mr. Roy N. Covert, who assisted in the standardization of pyranometers No. $1_{bis}$, No. 2, and No. 3, at Washington, D. C., made the drawings for figures 1 and 2, and made all the readings at radiation stations No. 3 and No. 5, Ellijay, N. C., and at No. 3, Highlands, N. C.; and to Mr. I. F. Hand, who made many of the radiation measurements at Mount Weather, Va., and Washington, D. C.

[14] *Blair, Wm. R.* Op. cit., p. 179, fig. 1.

[15] *Marvin, Chas. F.* Air drainage explained. MONTHLY WEATHER REVIEW, October, 1914, **42**: 583–585.

## MOLECULAR SCATTERING OF LIGHT.

[*Reprinted from* Nature, London, Feb. 14, 1918, 100: 473.]

In a paper communicated to the Astronomical Society of France (L'Astronomie, January), Prof. *Ch. Fabry* gives an account of Lord Rayleigh's explanation of the blue coloration of the sky, and announces that the theory has been experimentally verified in his laboratory at Marseilles by M. Cabannes. Prof. Fabry suggests that several hitherto mysterious phenomena in the heavens may possibly be explained as effects of this scattering of light by gaseous molecules. In the case of the solar corona, for example, the portion of the luminosity which gives a continuous spectrum does not necessarily imply the presence of solid or liquid particles, but may be attributed to the diffusion of photospheric light by molecules of truly gaseous coronal matter. A density of only 1/1,000,000,000 part of that of atmospheric air would suffice to account for the observed intensity of the coronal light, and the polarization of the light would be simply explained, as in the case of the light of the sky. A part of the luminosity of the tails of comets may be explained in a similar manner, and in this case the density must be less than one milligram per 1,000 cubic meters, as otherwise the luminosity would be greater than any which has ever been observed. Other possible effects of molecular scattering are also suggested. It may be added that Prof. R. J. Strutt has also succeeded in observing the scattering of light by dust-free air in a laboratory experiment with artificial illumination (Nature, Oct., 1917).[1]

[1] Reprinted in this REVIEW, October, 1917, p. 485.

## SECTION II.—GENERAL METEOROLOGY.

### PARTIAL CORRELATION APPLIED TO DAKOTA DATA ON WEATHER AND WHEAT YIELD.

By THOMAS ARTHUR BLAIR, Observer.

[Weather Bureau, Salt Lake City, Utah, Jan. 29, 1918.]

In papers previously published [1] the writer has shown:

(1) A definite relation between the rainfall of May and June and the yield of spring wheat in the Dakotas. This relation was expressed by the coefficients of correlation, $r = +0.63 \pm 0.05$ for North Dakota, and $+0.59 \pm 0.06$ for South Dakota.

(2) A negative relation of somewhat greater value between the June temperatures and the wheat yield, the coefficients being $-0.67 \pm 0.08$ and $-0.73 \pm 0.07$, respectively.

Since we have here three related variables capable of statistical statement, it seems advisable to extend the study of their mutual relations by the application of the method of "partial correlation." At the same time opportunity is taken to bring the tables down to date, and to present a brief explanation of the meaning and application of coefficients of "net" or "partial correlation."

The manner of constructing a correlation table and of computing coefficients of gross correlation has been frequently explained in recent issues of the MONTHLY WEATHER REVIEW,[2] is illustrated in Tables 1 and 2, herewith, and will need no further explanation. In addition to the correlations of yield with precipitation and temperature, there has been added in these tables a computation of the coefficient of correlation between precipitation and temperature. This shows for each State a rather high negative value. In other words, that the wet Mays and Junes in the Dakotas are in general the cool Junes. In view of this fact, the question naturally arises as to how much of the apparent relation between precipitation and yield, shown by the coefficients 0.611 and 0.487, is really due to the influence of precipitation, and how much is due to the simultaneous influence of temperature; and similarly, how much of the apparent relation between temperature and yield is due to precipitation.

*Partial correlation coefficients.*—Partial correlation coefficients enable us to answer such questions as these. In other words, they express the correlation between two related variables after eliminating the influence of one or more other variables, or, on the supposition that the other variables become constants. In the case of three quantities, the partial coefficient is given by the equation

$$r_{12\cdot 3} = \frac{r_{12} - r_{13}r_{23}}{\sqrt{(1-r_{13}^2)(1-r_{23}^2)}}$$

In this equation, the variables are numbered 1, 2, and 3 and the terms $r_{12}$, $r_{13}$, and $r_{23}$ are the ordinary coefficients of total correlation between the two variables indicated by the subscripts, and $r_{12\cdot 3}$ is the coefficient of partial correlation between the quantities 1 and 2 after eliminating the influence of 3. In the general case, for any number of variables, the equation becomes

$$r_{12\cdot 345\cdots n} = \frac{r_{12\cdot 45\cdots n} - r_{13\cdot 45\cdots n}\, r_{23\cdot 45\cdots n}}{\sqrt{(1-r_{13\cdot 45\cdots n}^2)(1-r_{23\cdot 45\cdots n}^2)}}$$

in which each of the terms represented by $r$ is the partial correlation coefficient between the two variables before the period when the effect of the quantities following the period is taken into account. The numerical solution requires the successive application of these two equations eliminating one variable at a time.

In the case under consideration, we have only the three quantities, precipitation, temperature, and yield to consider, and representing these by the letters, $p$, $t$, and $y$, we can at once write the equations as follows:

$$r_{py\cdot t} = \frac{r_{py} - r_{pt}\, r_{ty}}{\sqrt{(1-r_{pt}^2)(1-r_{ty}^2)}}$$

$$r_{ty\cdot p} = \frac{r_{ty} - r_{pt}\, r_{py}}{\sqrt{(1-r_{pt}^2)(1-r_{py}^2)}}$$

$$r_{pt\cdot y} = \frac{r_{pt} - r_{py}\, r_{ty}}{\sqrt{(1-r_{py}^2)(1-r_{ty}^2)}}$$

Substituting the values given in Tables 1 and 2, and solving, we have

For North Dakota:

$$r_{py\cdot t} = \frac{0.611-(-0.376)(-0.448)}{\sqrt{\{1-(-0.376)^2\}\{1-(-0.448)^2\}}} = \frac{0.4425}{0.8283} = +0.534,$$

$$r_{ty\cdot p} = \frac{-0.448-(-0.376)(0.611)}{\sqrt{\{1-(-0.376)^2\}\{1-(0.611)^2\}}} = \frac{-0.2183}{0.7335} = -0.298,$$

$$r_{pt\cdot y} = \frac{-0.376-(0.611)(-0.448)}{\sqrt{\{1-(0.611)^2\}\{1-(-0.448)^2\}}} = \frac{-0.1023}{0.7078} = -0.144,$$

For South Dakota:

$$r_{py\cdot t} = \frac{0.487-(-0.555)(-0.622)}{\sqrt{\{1-(-0.555)^2\}\{1-(-0.622)^2\}}} = \frac{0.1418}{0.6513} = +0.218,$$

$$r_{ty\cdot p} = \frac{-0.622-(-0.555)(0.487)}{\sqrt{\{1-(-0.555)^2\}\{1-(0.487)^2\}}} = \frac{-0.3517}{0.7266} = -0.484,$$

$$r_{pt\cdot y} = \frac{-0.555-(0.487)(-0.622)}{\sqrt{\{1-(0.487)^2\}\{1-(-0.622)^2\}}} = \frac{-0.2521}{0.6839} = -0.369.$$

We may summarize the results thus, dropping the third figure,

North Dakota:

$$r_{py} = +0.61; \quad r_{ty} = -0.45; \quad r_{pt} = -0.38;$$

$$r_{py\cdot t} = +0.53; \quad r_{ty\cdot p} = -0.30; \quad r_{pt\cdot y} = -0.14;$$

South Dakota:

$$r_{py} = +0.49; \quad r_{ty} = -0.62; \quad r_{pt} = -0.56;$$
$$r_{py\cdot t} = +0.22; \quad r_{ty\cdot p} = -0.48; \quad r_{pt\cdot y} = -0.37.$$

The coefficients of total correlation, it will be noted, are here somewhat smaller than in the original calculation for the shorter period.

*Interpretation of results.*—The actual relation between the data for precipitation and yield is shown by the coefficients +0.61 and +0.49; but these are reduced to +0.53 and +0.22 by eliminating the influence of temperature, and these latter thus become the expression of the real causative relation between precipitation as such

[1] MONTHLY WEATHER REVIEW, October, 1913, **41**: 1515–1517. MONTHLY WEATHER REVIEW, January, 1915, **43**: 24–26.

[2] See especially *Marvin, C. F.*: Elementary notes on least squares, etc. MONTHLY WEATHER REVIEW, October, 1916, **44**: 551–569.

and yield. A considerable part of the apparent effect of precipitation upon yield is thus seen to be due to the influence of the accompanying temperatures upon the yield. Similarly, the real effect of temperature alone is shown by the coefficients −0.30 and −0.48 instead of −0.45 and −0.62. The interrelation of the three factors is thus clearly shown; and, further, the values +0.53 and −0.30 show that for North Dakota the net effect of precipitation is greater than that of temperature, while, on the other hand, in South Dakota the influence of temperature is the greater, as shown by the coefficients +0.22 and −0.48. We are aware, of course, that the precipitation of May and June and the temperature of June are not the only influences determining the final yield of wheat, and this is indicated in these results by the fact that the values found for the net coefficients do not approximate unity. If we could take account of all the factors, we should be able to find a coefficient of partial correlation between the yield and any one of them which would be approximately +1 or −1. The magnitude of the coefficients here found is sufficient evidence that the precipitation and temperature expressed in monthly sums and means are two of the important factors affecting yield, but not the only important factors.

The values of $r_{pt}$ disclose a meteorologically interesting connection between precipitation and temperature, which need not be here discussed. It is necessary, however, to notice the relative values of the coefficients $r_{pt}$ and $r_{pt\cdot y}$, for these illustrate an important point in interpreting the results of partial correlations, showing the necessity for care in arriving at the true significance of such functions. We note that the relations between precipitation and temperature, −0.38 and −0.56, are reduced to −0.14 and −0.37 when we consider yield. Now, to follow strictly the line of argument used in interpreting the other partial coefficients would lead to the reductio ad absurdum that the summer yield of wheat affected the relation between the temperature and precipitation of the previous May and June. The point to be noted is that in properly interpreting coefficients of partial correlation we must be able to determine from other considerations which of the variables are causes and which are effects. In the problem under consideration there is evidently no difficulty on this score: we know that yield is an effect and the other variables are causes. The relation actually obtaining between precipitation and temperature is expressed by the coefficient $r_{pt}$, and the meaning of $r_{pt\cdot y}$ is that if the yield had been the same, a different relation would have subsisted between precipitation and temperature, which is but another way of arriving at the general conclusion that there is a real relation between precipitation, temperature, and yield.

## CONCLUSIONS.

(1) The precipitation of May and June and the temperature of June are important factors, but not the only important factors, affecting the yield of wheat in the Dakotas.

(2) A considerable part of the apparent effect of either precipitation or temperature upon yield is really due to the accompanying effect of the other.

(3) In North Dakota the influence of precipitation is greater than that of temperature, while the reverse is true in South Dakota.

(4) When the precipitation of May and June is above the average in the Dakotas the temperature of June is generally below the average, and inversely.

TABLE 1.—*Correlation between the rainfall of May and June, the temperature of June, and the yield per acre of spring wheat in North Dakota.*

| Year. | May and June rainfall. | | | June temperature. | | | Yield. | | | $pt$. | $py$. | $ty$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Amt. | Departure $p$. | $p^2$. | Mean. | Departure $t$. | $t^2$. | Amt. | Departure $y$. | $y^2$. | | | |
| | *In.* | | | °*F.* | | | *Bus. acre.* | | | | | |
| 1892.. | 5.6 | −0.5 | 0.25 | 60.5 | −2.1 | 4.41 | 12.2 | +0.1 | 0.01 | + 1.05 | − 0.05 | − 0.21 |
| 1893.. | 5.0 | −1.1 | 1.21 | 67.4 | +4.8 | 23.04 | 9.6 | −2.5 | 6.25 | − 5.28 | + 2.75 | −12.00 |
| 1894.. | 5.0 | −1.1 | 1.21 | 68.8 | +6.2 | 38.44 | 11.8 | −0.3 | 0.09 | − 6.82 | + 0.33 | − 1.86 |
| 1895.. | 7.3 | +1.1 | 1.21 | 59.7 | −2.9 | 8.41 | 21.0 | +8.9 | 79.21 | − 3.19 | + 9.79 | −25.81 |
| 1896.. | 8.7 | +2.6 | 6.76 | 65.6 | +3.0 | 9.00 | 11.8 | −0.3 | 0.09 | + 7.80 | − 0.78 | − 0.90 |
| 1897.. | 4.5 | −1.6 | 2.56 | 61.7 | −0.9 | 0.81 | 10.3 | −1.8 | 3.24 | + 1.44 | + 2.88 | + 1.62 |
| 1898.. | 5.2 | −0.9 | 0.81 | 62.6 | 0 | 0 | 14.4 | +2.3 | 5.29 | 0 | − 2.07 | 0 |
| 1899.. | 7.3 | +1.2 | 1.44 | 62.2 | −0.4 | 0.16 | 12.8 | +0.7 | 0.49 | − 0.48 | + 0.84 | − 0.28 |
| 1900.. | 2.1 | −4.0 | 16.00 | 66.9 | +4.3 | 18.49 | 4.9 | −7.2 | 51.84 | −17.20 | +28.80 | −30.96 |
| 1901.. | 6.5 | +0.4 | 0.16 | 61.6 | −1.0 | 1.00 | 13.1 | +1.0 | 1.00 | − 0.40 | + 0.40 | − 1.00 |
| 1902.. | 7.2 | +1.1 | 1.21 | 58.0 | −4.6 | 21.16 | 15.9 | +3.8 | 14.44 | − 5.06 | + 4.18 | −17.48 |
| 1903.. | 4.5 | −1.6 | 2.56 | 62.4 | −0.2 | 0.04 | 12.7 | +0.6 | 0.36 | + 0.32 | − 0.96 | − 0.12 |
| 1904.. | 7.5 | +1.4 | 1.96 | 61.4 | −1.2 | 1.44 | 11.8 | −0.3 | 0.09 | − 1.68 | − 0.42 | + 0.36 |
| 1905.. | 7.6 | +1.5 | 2.25 | 59.7 | −2.9 | 8.41 | 14.0 | +1.9 | 3.61 | − 4.35 | + 2.85 | − 5.51 |
| 1906.. | 8.7 | +2.6 | 6.76 | 62.0 | −0.6 | 0.36 | 13.0 | +0.9 | 0.81 | − 1.56 | + 2.34 | − 0.54 |
| 1907.. | 4.0 | −2.1 | 4.41 | 61.9 | −0.7 | 0.49 | 10.0 | −2.1 | 4.41 | + 1.47 | + 4.41 | + 1.47 |
| 1908.. | 6.3 | +0.2 | 0.01 | 60.4 | −2.2 | 4.84 | 11.6 | −0.5 | 0.25 | − 0.44 | − 0.10 | + 1.10 |
| 1909.. | 6.5 | +0.4 | 0.16 | 62.9 | +0.3 | 0.09 | 13.7 | +1.6 | 2.56 | + 0.12 | + 0.64 | + 0.48 |
| 1910.. | 2.8 | −3.3 | 10.89 | 67.3 | +4.7 | 22.09 | 5.5 | −6.6 | 43.56 | −15.51 | +21.78 | −31.02 |
| 1911.. | 6.0 | −0.1 | 0.01 | 66.9 | +4.3 | 18.49 | 8.0 | −4.1 | 16.81 | − 0.43 | + 0.41 | −17.63 |
| 1912.. | 6.6 | +0.5 | 0.25 | 61.8 | −0.8 | 0.64 | 18.0 | +5.9 | 34.81 | − 0.40 | + 2.95 | − 4.72 |
| 1913.. | 4.0 | −2.1 | 4.41 | 65.8 | +3.2 | 10.24 | 10.5 | −1.6 | 2.56 | − 6.72 | + 3.36 | − 5.12 |
| 1914.. | 8.4 | +2.3 | 5.29 | 62.2 | −0.4 | 0.16 | 11.2 | −0.9 | 0.81 | − 0.92 | − 2.07 | + 0.36 |
| 1915.. | 8.2 | +2.1 | 4.41 | 56.7 | −5.9 | 34.81 | 18.2 | +6.1 | 37.21 | −12.39 | +12.81 | −35.99 |
| 1916.. | 6.1 | 0 | 0 | 58.2 | −4.4 | 19.36 | 5.5 | −6.6 | 43.56 | 0 | 0 | +29.04 |
| 1917.. | 2.4 | −3.7 | 13.69 | 58.5 | −4.1 | 16.81 | 8.2 | −3.9 | 15.21 | +15.17 | +14.43 | +15.99 |
| Sums. | .... | −4.7 | 89.91 | .... | −4.5 | 263.19 | ..... | −4.9 | 368.57 | −55.46 | +109.50 | −140.73 |
| Means | 6.1 | −0.18 | ..... | 62.6 | −0.17 | ..... | 12.1 | −0.20 | ..... | ..... | ..... | ..... |

*Table 1—computations.*

$[p] = -4.7$; $[t] = -4.5$; $[y] = -4.9$;
$[p^2] = 89.91$; $[t^2] = 263.19$; $[y^2] = 368.57$;
$[py] = 109.50$; $[ty] = -140.73$; $[pt] = -55.46$;
$n = 26$.

$$\sigma_p = \sqrt{\frac{[p^2] - \frac{[p]^2}{n}}{n}} = \sqrt{\frac{89.91 - \frac{(-4.7)^2}{26}}{26}},$$

$$= \sqrt{\frac{89.06}{26}} = \sqrt{3.43} = 1.8;$$

$$\sigma_t = \sqrt{\frac{263.19 - \frac{(-4.5)^2}{26}}{26}} = \sqrt{\frac{262.41}{26}} = \sqrt{10.09} = 3.2$$

$$\sigma_y = \sqrt{\frac{368.57 - \frac{(-4.9)^2}{26}}{26}} = \sqrt{\frac{367.65}{26}} = \sqrt{14.14} = 3.8$$

$$r_{py} = \frac{[py] - \frac{[p]\,[y]}{n}}{n\sigma_p\sigma_y} = \frac{109.50 - \frac{(-4.7)\,(-4.9)}{26}}{26 \times 1.8 \times 3.8}$$

$$= \frac{109.50 - 0.89}{177.84} = \frac{108.61}{177.84} = +0.611$$

$$r_{ty} = \frac{-140.73 - \frac{(-4.5)\,(-4.9)}{26}}{26 \times 3.2 \times 3.8} = \frac{-140.73 - 0.85}{316.16},$$

$$= \frac{-141.58}{316.16} = -0.448$$

$$r_{pt} = \frac{-55.46 - \frac{(-4.7)\,(-4.5)}{26}}{26 \times 1.8 \times 3.2} = \frac{-55.46 - 0.81}{149.76},$$

$$= \frac{-56.27}{149.76} = -0.376$$

$$Er_{py} = \pm 0.6745 \frac{1 - r_{py}^2}{\sqrt{n}} = \frac{\pm 0.6745}{5.1} \times 0.6267,$$

$$= \pm 0.083$$

$$Er_{ty} = \pm \frac{0.6745}{5.1} \times 0.7993 = \pm 0.106,$$

$$Er_{pt} = \pm \frac{0.6745}{5.1} \times 0.8586 = \pm 0.113;$$

TABLE 2.—*Correlation between the rainfall of May and June, the temperature of June, and the yield of spring wheat per acre, in South Dakota.*

| Year. | Precipitation. | | | Temperature. | | | Yield. | | | $pt$. | $py$. | $ty$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Amt. | Departure $p$. | $p^2$. | Mean. | Departure $t$. | $t^2$. | Amt. | Departure $y$. | $y^2$. | | | |
| | *In.* | | | °*F.* | | | *Bus. acre.* | | | | | |
| 1891.. | 6.5 | −0.3 | 0.09 | 64.2 | −1.7 | 2.89 | 15.2 | +4.0 | 16.00 | +0.51 | −1.20 | −6.80 |
| 1892.. | 9.5 | +2.7 | 7.29 | 63.9 | −2.0 | 4.00 | 12.5 | +1.3 | 1.69 | −5.40 | +3.51 | −2.60 |
| 1893.. | 4.5 | −2.3 | 5.29 | 70.3 | +4.4 | 19.36 | 8.5 | −2.7 | 7.29 | −10.12 | +6.21 | −11.88 |
| 1894.. | 3.7 | −3.1 | 9.61 | 70.6 | +4.7 | 22.09 | 6.6 | −4.6 | 21.16 | −14.57 | +14.26 | −21.62 |
| 1895.. | 6.9 | +0.1 | 0.01 | 63.7 | −2.2 | 4.84 | 12.0 | +0.8 | 0.64 | − 0.22 | +0.08 | −1.76 |
| 1896.. | 6.6 | −0.2 | 0.04 | 67.0 | +1.1 | 1.21 | 11.2 | 0 | 0 | −0.22 | 0 | 0 |
| 1897.. | 4.6 | −2.2 | 4.84 | 65.0 | −0.9 | 0.81 | 8.0 | −3.2 | 10.24 | +1.98 | +7.04 | +2.88 |
| 1898.. | 6.8 | 0 | 0 | 67.3 | +1.4 | 1.96 | 12.4 | +1.2 | 1.44 | 0 | 0 | +1.68 |
| 1899.. | 8.1 | +1.3 | 1.69 | 66.4 | +0.5 | 0.25 | 10.7 | −0.5 | 0.25 | +0.65 | −0.65 | −0.25 |
| 1900.. | 3.5 | −3.3 | 10.89 | 69.4 | +3.5 | 12.25 | 6.9 | −4.3 | 18.49 | −11.55 | +14.19 | −15.05 |
| 1901.. | 8.1 | +1.3 | 1.69 | 66.3 | +0.4 | 0.16 | 12.9 | +1.7 | 2.89 | +0.52 | +2.21 | +0.68 |
| 1902.. | 6.0 | −0.8 | 0.64 | 62.6 | −3.3 | 10.89 | 12.2 | +1.0 | 1.00 | +2.64 | −0.80 | −3.30 |
| 1903.. | 7.0 | +0.2 | 0.04 | 65.0 | −0.9 | 0.81 | 13.8 | +2.6 | 6.76 | −0.18 | +0.52 | −2.34 |
| 1904.. | 6.5 | −0.3 | 0.09 | 64.5 | −1.4 | 1.96 | 9.6 | −1.6 | 2.56 | +0.42 | +0.48 | +2.24 |
| 1905.. | 11.6 | +4.8 | 23.04 | 64.4 | −1.5 | 2.25 | 13.7 | +2.5 | 6.25 | −7.20 | +12.00 | −3.75 |
| 1906.. | 8.4 | +1.6 | 2.56 | 63.9 | −2.0 | 4.00 | 13.4 | +2.2 | 4.84 | −3.20 | +3.52 | −4.40 |
| 1907.. | 7.7 | +0.9 | 0.81 | 64.2 | −1.7 | 2.89 | 11.2 | 0 | 0 | −1.53 | 0 | 0 |
| 1908.. | 10.0 | +3.2 | 10.24 | 63.7 | −2.2 | 4.84 | 12.8 | +1.6 | 2.56 | −7.04 | +5.12 | −3.52 |
| 1909.. | 9.0 | +2.2 | 4.84 | 66.9 | +1.0 | 1.00 | 14.1 | +2.9 | 8.41 | +2.20 | +6.38 | +2.90 |
| 1910.. | 3.9 | −2.9 | 8.41 | 68.3 | +2.4 | 5.76 | 12.8 | +1.6 | 2.56 | −6.96 | −4.64 | +3.84 |
| 1911.. | 3.6 | −3.2 | 10.24 | 73.4 | +7.5 | 56.25 | 4.0 | −7.2 | 51.84 | −24.00 | +23.04 | −54.00 |
| 1912.. | 3.8 | −3.0 | 9.00 | 64.8 | −1.1 | 1.21 | 14.2 | +3.0 | 9.00 | +3.30 | −9.00 | −3.30 |
| 1913.. | 6.0 | −0.8 | 0.64 | 69.6 | +3.7 | 13.69 | 9.0 | −2.2 | 4.84 | −2.96 | +1.76 | −8.14 |
| 1914.. | 8.1 | +1.3 | 1.69 | 67.5 | +1.6 | 2.56 | 9.0 | −2.2 | 4.84 | +2.08 | −2.86 | −3.52 |
| 1915.. | 9.0 | +2.2 | 4.84 | 60.4 | −5.5 | 30.25 | 17.0 | +5.8 | 33.64 | −12.10 | +12.76 | −31.90 |
| 1916.. | 8.2 | +1.4 | 1.96 | 61.5 | −4.4 | 19.36 | 6.3 | −4.9 | 24.01 | −6.16 | −6.86 | +21.56 |
| 1917.. | 5.3 | −1.5 | 2.25 | 62.7 | −3.2 | 10.24 | 14.0 | +2.8 | 7.84 | +4.80 | −4.20 | −8.96 |
| Sums. | .... | −0.7 | 122.73 | .... | −1.8 | 237.78 | ..... | +1.6 | 251.04 | −94.31 | +82.87 | −151.31 |
| Means | 6.8 | −0.02 | ..... | 65.9 | −0.07 | ..... | 11.2 | +0.06 | ..... | ..... | ..... | ..... |

*Table 2—computations.*

$$[p]=-0.7;\quad [t]=-1.8;\quad [y]=+1.6;$$
$$[p^2]=122.73;\quad [t^2]=237.78;\quad [y^2]=251.04;$$
$$[py]=82.87;\quad [ty]=-151.31;\quad [pt]=-94.31;$$
$$n=27;$$

$$\sigma_p=\sqrt{\frac{[p^2]-\frac{[p]^2}{n}}{n}}=\sqrt{\frac{122.73-\frac{(-0.7)^2}{27}}{27}}$$

$$=\sqrt{\frac{122.71}{27}}=\sqrt{4.54}=2.1$$

$$\sigma_t=\sqrt{\frac{237.78-\frac{(-1.8)^2}{27}}{27}}=\sqrt{\frac{237.66}{27}}=\sqrt{8.80}=3.0$$

$$\sigma_y=\sqrt{\frac{251.04-\frac{(1.6)^2}{27}}{27}}=\sqrt{\frac{250.95}{27}}=\sqrt{9.29}=3.0$$

$$r_{py}=\frac{[py]-\frac{[p]\,[y]}{n}}{n\,\sigma_p\sigma_y}=\frac{82.87-\frac{(-0.7)\,(1.6)}{27}}{27\times2.1\times3.0}$$

$$=\frac{82.87+.04}{170.10}=\frac{82.91}{170.10}=+0.487$$

$$r_{ty}=\frac{-151.31-\frac{(-1.8)\,(1.6)}{27}}{27\times3.0\times3.0}=-\frac{151.31+0.10}{243.00}$$

$$=\frac{-151.21}{243.00}=-0.622.$$

$$r_{pt}=\frac{-94.31-\frac{(-0.7)\,(-1.8)}{27}}{27\times2.1\times3.0}=\frac{-94.31-0.05}{170.10}$$

$$=\frac{-94.36}{170.10}=-0.555$$

$$Er_{py}=\pm0.6745\,\frac{1-r_{py}^2}{\sqrt{n}}=\pm\frac{0.6745}{5.2}\times0.7629=\pm0.099$$

$$Er_{ty}=\pm\frac{0.6745}{5.2}\times0.6131=\pm0.080$$

$$Er_{pt}=\pm\frac{0.6745}{5.2}\times0.6920=\pm0.090$$

## NOMENCLATURE OF THE UNIT OF ABSOLUTE PRESSURE.

By CHARLES F. MARVIN.

[Weather Bureau, Washington, Mar. 30, 1918.]

While scientists are striving to secure international uniformity of units, nevertheless, right in our midst we find growing up a diversity of practice which all must deplore, regarding the nomenclature of pressure in absolute units, and which if not soon remedied will result in much future confusion. Pressure can be conceived only with reference to some area over which it acts, and pressure multiplied by area is a force. Since the dyne is the standard unit of force, a pressure of 1 dyne per square centimeter seems to constitute the logical unit of pressure. Indeed, since the concept pressure is inseparable from some area, science might be willing to grant that expressions like "a pressure of 1 dyne" has the same meaning as "a pressure of 1 dyne *per square centimeter*", etc., unless some other area is named. In other words, a unit of pressure is a unit of force on a unit area, and no particular name for this unit is really required. The practice and usage through the course of the last decade or more relative to the introduction of the names "barad", "barye", "bar", etc., as names for absolute units of pressure is briefly indicated in the following statement from notes furnished by C. F. Talman and Cleveland Abbe, jr., United States Weather Bureau.

A committee on uniformity of units of the British Association for the Advancement of Science recommended (see report of the Association for 1888, p. 28):

> The unit of pressure on the C. G. S. system of units, i. e., the pressure of 1 dyne per square centimeter, to be called 1 barad.

At the International Physics Congress at Paris, 1900, M. Guillaume proposed that the name *barye* be applied to the megadyne per square centimeter. His proposal was referred to a committee on units, of which he was a member. This committee unanimously recommended that the name *barye* be applied to the dyne, instead of the megadyne, per square centimeter. The report of the committee was presented at the final session of the congress, but, *so far as appears from the procès-verbaux, no action was taken on it.*

T. W. Richards [1] and A. E. Kennelly [2] employed the term "bar" to signify a pressure of 1 dyne per square centimeter, having either selected the term independently or taken it as an abbreviated variation of the terms "barad" (British Association committee) or "barye" (Physicists' Congress, 1900). Other instances of restricted use of the terms barad and megabar are found; e. g., Tables of Physical and Chemical Constants, by Kaye and Laby (1911), page 5 and page 27, and Smithsonian Physical Tables, fifth and sixth editions, pages 309 and 346, respectively.

Meteorologists have long had occasion to express atmospheric pressures in absolute terms,[3] but it remained for Bjerknes to recognize the peculiar convenience in hydrodynamics and atmospherics of the megadyne per square centimeter as a unit of pressure, and, through his pupil J. W. Sandström,[4] to introduce it—without assigning it a special name at the time—in his epochal investigations into the hydrodynamics of the sea and the atmos-

[1] Richards, T. W., *in* Carnegie Institution of Washington, Publication No. **7**. Washington, 1903. pp. 42–43.

[2] Kennelly, A. E., *in* Proc. Am. instit. elect. eng., 1909, **28**: 706.

[3] e. g., *Abbe, C.* Preparatory studies for deductive methods in storm and weather predictions. Washington, 1890. p. 62. (Ann. rpt., C. S. O., 1889, App. 15.)

[4] *Sandström, J. W., & Helland-Hansen, B.* Ueber die Berechnung von Meeresströmungen. Bergen, 1903. 8°. pp. 2, 14–15. (Report on Norwegian fishery and marine investigations, v. 2, 1902, No. 4.)

phere. It soon became desirable to avoid the circumlocution of calling the unit "one million dynes per square centimeter", and Bjerknes proposed to call it the "bar" =1 megadyne per square centimeter, with its subdivisions of decibar, centibar, millibar, etc., in accordance with the method of numeration of the C. G. S. system.[5] Prof. Bjerknes' own account of the origin of this unit, the "bar", follows.[6]

When fourteen years ago I began to occupy myself with problems concerning the dynamics of the atmosphere and the sea, I encountered many difficulties of terminology. Cumbrous expressions such as: "Pressure at that height where gravity potential is $x.10^5$ C. G. S.-units", or "gravity-potential at that height where pressure is $y.10^3$ C. G. S.-units", as well as the corresponding expressions concerning dynamic conditions at different depths in the sea, recurred again and again, often on the same page. I therefore coined the terms "bar", "decibar", "centibar", and "millibar", as names for the units of pressure; "dynamic height", "dynamic depth", as synonyms for gravity-potential, and finally "dynamic metre", "dynamic decimetre", etc., for the units of this quantity. In place, then, of the cumbrous expressions which prevailed formerly, we now have "Pressure at the height of $x$ dynamic metres", "Dynamic height of the pressure $y$ mbar" with respect to the atmosphere, and with respect to the sea "Pressure at the depth of $x$ dynamic metres", "dynamic depth of the pressure $y$ dbar".

I employed these expressions for the first time in a paper published in 1906,[7] and expected that criticism would be directed against them, as the use of new terms usually provokes opposition; but they passed without comment, and consequently a discussion which might have proved fruitful did not arise. On the contrary, other writers found the expressions convenient and adopted them. They will be found throughout a series of important papers bearing upon hydrography by Sandström, V. W. Ekman, and Helland-Hansen, and they have, further, been regularly employed in the official publications of the "Conseil permanent International pour l'exploration de la mer" in Copenhagen.

No protests having appeared,[8] I did not scruple to make use of this terminology in my book "Dynamic Meteorology and Hydrography", of which the first two volumes have appeared both in English and in German. Should this book and its annexed numerical tables have given rise to a more extended use of the terminology from year to year, I am no longer able to prevent it. * * *

This system of nomenclature, according to which the millibar = 1,000 dynes per square centimeter, was urged upon meteorologists in 1909 by W. Köppen[9] also; and was formally adopted in 1912 for use in *aerology* by a recommendation of the International Commission for Scientific Aeronautics, at a meeting in Vienna in 1912, an action later approved by the International Meteorological Committee at the Rome session in 1913.

In the meantime the new units were introduced extensively into international statistical meteorology, as shown by the following statement.

The British Meteorological Office has used millibars in recording upper-air observations since 1907, and for general observations at "observatories" (i. e., certain first-order stations) since 1911. They have been used on the British daily weather map (Daily Weather Report) since May 1, 1914. All the regular British stations were equipped with barometers for reading to millibars during the year 1914. The Royal Meteorological Society has been engaged for some years in preparing new normals of atmospheric pressure for the British Isles, and has used the millibar in this compilation, which has not yet been published. (Ninth Annual Report Meteorological Committee, 1914, p. 63–65; Tenth Annual Report, 1915, p. 30). Millibars are used in the important international publications of the British Meteorological Office known as "Réseau Mondial", of which the first annual volume, corresponding to the year 1911, appeared in 1917.

Millibars have been used on the French daily weather map (Bulletin International Météorologique) since January 1, 1917, and it is understood that they have been adopted for general use by the French meteorological service (Bureau Central Météorologique de France) in publications of data for 1917 et seq. (None of these, except the weather map, has reached us.) Millibars have been adopted for official meteorological observations in the British colonies of Mauritius and British Guiana (Nature, London, Dec. 28, 1916, p. 332).

Millibars were used by the United States Weather Bureau on its Weather Map of the Northern Hemisphere, published January 1 to August 6, 1914. They have been used in the upper-air observations of the bureau since the publication, in 1916, of the data for 1915 (Monthly Weather Review Supplement No. 3, p. 5).

The International Meteorological Committee, at its meeting in Rome, 1913, requested the International Commission for Scientific Aeronautics to publish upper-air data in both millimeters and millibars, beginning with the observations for the year 1913.

The publication of aerological observations has been greatly delayed by the present war, but reports of kite and balloon observations now being received from the Canadian Meteorological Office, give pressures in conformity with the vote of the International Meteorological Committee.

[So far as known to the Weather Bureau, the Blue Hill Observatory, whose reports are published in the Annals of Harvard College Observatory, is the only meteorological institution in the world that publishes its pressure observations in units of 1 bar=1 dyne per square centimeter.]

Committees of the British Association and of the International Physical Congress of 1900 voted in favor of the names *barad* and *barye*, respectively, for the unit 1 dyne per square centimeter. The growing tendency among chemists and physicists seems to be, however, to neglect these names proposed by their own conventions and to employ the terms *bar* adopted by the International Meteorological Committee, but giving to it a new value only one-millionth as large as that voted by the Committee which adopted it.

The confusion arising from this diversity of usage could, of course, be partly avoided by a strict discrimination between the terms "bar" on the one hand and

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[5] *Bjerknes, V., & Sandström, J. W.* Hilfsgrössen zur Berechnung der Druckverteilung in der Atmosphäre an der internationalem Tagen 1900–1903. Beiträge zur Physik d. fr. Atmosphäre, Strassburg, 1906, **2**, heft 1, 1–17, 2 plates.

*Knudsen, Martin*, in Bull. trimestr., Permanent. internat. conseils f. Meeresforsch., København, 1905–6, No. 1, Pt. B, p. 65 and charts. [Knudsen here simply states "As the unit of pressure has been chosen a pressure of $10^6$ C. G. S. units, it is nearly equal to 1/10 atmosphere and is called a decibar . . ." This publication has continued the use of the unit to date.]

[6] Quarterly journal, Royal meteorological society, London, April 1914, **40**: 160, fig.

[7] *Bjerknes, V., & Sandström, J. W.*, op. cit., Beitr. z. Phys. d. freien Atmosphäre, 1906, **2**:1, where they write as follows: ". . . Da unser Ziel eine weitergehende Diskussion der Dynamik der Atmosphäre ist, können wir uns nur mit absoluter Masse bedienen. Daher muss die gewöhnliche irrationelle Druckeinheit, das mm Hg., aufgeben und durch eine entsprechende, dem absoluten Masssysteme angehörende Einheit ersetzt werden. Als solche praktische Einheit ist oft die Megadyne pro Quadratzentimeter vorgeschlagen worden. Diese Einheit werden wir ein *Bar* nennen. Das Bar wird in Dezi-, Zenti-, und Millibar geteilt, und das *Millibar* ersetzt das mm Hg. Das Millibar beträgt sehr nahe $\frac{3}{4}$ oder genauer 0.75006 mm Hg." [They continue with a description of the "dynamic meter" and its advantages.] —C. A., jr.

[8] The protest published by A. E. Kennelly, this REVIEW, March, 1914, **42**: 141, came too late; and the proposal by T. W. Richards there quoted probably escaped the attention of all meteorologists because not earlier published in a meteorological journal.—C. A., jr.

[9] *Köppen, Wladimir.* Vorschlag, alle Luftdruckmessungen in allgemeinem Kraftmass anzugeben. Meteorol. Ztschr., Braunschweig, Mai, 1909, **26**: 198–201.

*Do.* Express all barometric measurements by ordinary general units of force. MONTHLY WEATHER REVIEW, Washington, March, 1909, **37**: 92–93.

"barad" or "barye" on the other. This discrimination is seemingly as justifiable as that now fully established and familiar to all in the signification of such prefixes as deci- and deka-.

For the purpose of contrasting the application of the dual system of terminology to the various requirements of science, I tabulate below the names and magnitudes of certain of the more familiar pressures dealt with by meteorologists, physicists, and others.

*Comparison of scales of pressure now in use and their terminologies.*

| Nature of the pressure. | Meteorological scale. 1 bar=1 megadyne per square centimeter. | Physical scale. 1 barad / 1 barye = 1 dyne per square centimeter. |
|---|---|---|
| Residual gas pressure in highly exhausted vacua, as in electric-light bulbs, X-ray tubes, etc. | Very high vacua=0.01 microbar. | =1 centibarad. |
| | Ordinary vacua=1 to 100 microbars. | =1 to 100 barads. |
| Pressure in highest regions of the atmosphere yet attained by sounding balloons (33 kilometers). | =10 millibars..... | =10 kilobarads. |
| Pressure of a wind blowing about 50 miles per hour against a wall, a person walking, etc. | =4 millibars..... | =4 kilobarads. |
| Sustaining pressure on the supporting wing of airplanes (approximate). | =2 to 2.5 millibars..... | =2 to 2.5 kilobarads. |
| *Atmospheric pressure* at about 100 meters above mean sealevel. | =1 bar=1,000 millibars.. | =1 megabarad=1,000 kilobarads=1,000,000 barads. |
| Pressure of water vapor at its critical temperature. | =220 bars..... | =220 megabarads. |
| Pressures at the greatest depths of the sea (10 kilometers). | =1 megabar=1,000,000 bars. | =1,000,000 megabarads. (No customary prefix of higher significance than "mega-" is available.) |
| Still greater pressures within the domain of geophysics and elsewhere. | Conveniently expressed in terms of megabars with *convenient* numerical factors. | No convenient term available. Requires the term "megabarad" with *large* numerical factors. |

It is apparent from this table that probably little or no occasion will ever arise in science to make practical use of the subdivisions micro-, milli-, and centi*barad* of the physical scale, which moreover affords no convenient prefixes or terms to designate the very great pressures. In other words the unit, *barad*=1 dyne per square centimeter, is too small to conveniently meet the general requirements of all branches of science.

On the other hand, in the meteorological scale the submultiples micro-, milli-, centi-, and the unit itself, *bar*, are available to the fullest extent for the small pressures encountered in nature and the great multiples, expressed by the prefixes kilo- and mega-, are needed and available to designate the really great pressures with which science must also deal.

*Consistency.*—It is claimed the name *bar* must be consistently applied to the basic unit of the C. G. S. system. This argument from consistency loses force when it is noted that the whole C. G. S. system involves a kind of inconsistency of this character.[10]

The *meter* is the international standard of length, but the *centimeter* is adopted as the more convenient unit of length for the basis of the C. G. S. system.

The Director of the United States Bureau of Standards has kindly called my attention to a remedy for the inconvenience in practical science growing out of the size of the units of the C. G. S. system, which remedy was proposed by the International Association on Refrigeration meeting at Paris in June, 1909, and later considered and elaborated by the International Bureau of Weights and Measures.[11] This proposal offers a supplemental system of practical units based, like the C. G. S. system, on the fundamental units of length, mass and time, the units chosen being the meter, kilogram, and second, Here, again, the kilogram in this M.K.S. system introduces an inconsistency of the kind mentioned above for the C. G. S. system.[12] Entire consistency with an arbitrary ideal obviously can not be realized without radical changes in and modification of well-established nomenclature. Several important practical units conforming to the M. K. S. system have been defined and sanctioned by international convention.

The derived units in the C. G. S. system by convention are given names based on Greek roots, whereas the names of the derived units in the M. K. S. system are proposed to be based on the names of great scientists, as illustrated by Volt, Ampére, Watt, etc., and Pascal has been proposed as the name of the unit of pressure.

Summarizing the foregoing we may say that the International Committee on Scientific Aeronautics and the International Meteorological Committee formally adopted and recommended for international use the term *bar*, meaning a pressure of one megadyne per square centimeter, whereas the terms *barad* and *barye*, meaning a pressure of one dyne per square centimeter, have little or only a slender basis of international sanction and appear to be less acceptable to the physicists than the term *bar*, which they use with a different meaning than that sanctioned by international convention. Obviously, therefore, a condition of serious confusion exists in these matters, and it is earnestly hoped that means may be found whereby international action on the part of all interests concerned in this new pressure unit, can be secured at an early date in order to avoid the confusion that must otherwise result.

In the meantime, the U. S. Weather Bureau has no choice but to continue, and doubtless increase, its use of the *bar* as a unit of pressure, in accordance with international convention.

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## UNITED STATES DAYLIGHT SAVING ACT OF MARCH 19, 1918.

(The U. S. Weather Bureau is so deeply affected by the daylight-saving act that it seems desirable to reprint the text for convenience of future reference.—C. A., jr.)

AN ACT To save daylight and to provide standard time for the United States.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That for the purpose of establishing the standard time of the United States, the territory of continental United States shall be divided into five zones in the manner hereinafter provided. The standard time of the first zone shall be based on the mean astronomical time of the seventy-fifth degree of longitude west from Greenwich; that of the second zone on the ninetieth degree; that of the third zone on the one hundred and fifth degree; that of the fourth zone on the one hundred and twentieth degree; and that of the fifth zone, which shall include only Alaska, on the one hundred and fiftieth degree. That the limits of each zone shall be defined by an order of the Interstate Commerce Commission, having regard for the convenience of commerce and the existing junction points and division points of common carriers engaged in commerce between the several States and with

[10] See also the discussion of consistency in MONTHLY WEATHER REVIEW, March, 1914, **42**: 142.

[11] Procès-Verbaux. 1911. p. 209. Comptes Rendus of the Conférence Générale des Poids et Mesures. 1913. p. 14; 51–60.

[12] See discussions of the proposed units of acceleration and geopotential, "gal", "leo", "leometer", etc., in this REVIEW, January, 1914, **42**: 6, 142, 539. *Also* The Observer's Handbook (Met'l. Off. no. 191), 1913 ed., p. xxiii; 1917 ed., p. xxiii, xxv.

foreign nations, and such order may be modified from time to time.

SEC. 2. That within the respective zones created under the authority hereof the standard time of the zone shall govern the movement of all common carriers engaged in commerce between the several States or between a State and any of the Territories of the United States, or between a State or the Territory of Alaska and any of the insular possessions of the United States or any foreign country. In all statutes, orders, rules, and regulations relating to the time of performance of any act by any officer or department of the United States, whether in the legislative, executive, or judicial branches of the Government, or relating to the time within which any rights shall accrue or determine, or within which any act shall or shall not be performed by any person subject to the jurisdiction of the United States, it shall be understood and intended that the time shall be the United States standard time of the zone within which the act is to be performed.

SEC. 3. That at two o'clock antemeridian of the last Sunday in March of each year the standard time of each zone shall be advanced one hour, and at two o'clock antemeridian of the last Sunday in October in each year the standard time of each zone shall, by the retarding of one hour, be returned to the mean astronomical time of the degree of longitude governing said zone, so that between the last Sunday in March at two o'clock antemeridian and the last Sunday in October at two o'clock antemeridian in each year the standard time in each zone shall be one hour in advance of the mean astronomical time of the degree of longitude governing each zone, respectively.[1]

SEC. 4. That the standard time of the first zone shall be known and designated as United States Standard Eastern Time; that of the second zone shall be known and designated as United States Standard Central Time; that of the third zone shall be known and designated as United States Standard Mountain Time; that of the fourth zone shall be known and designated as United States Standard Pacific Time; and that of the fifth zone shall be known and designated as United States Standard Alaska Time.

SEC. 5. That all acts and parts of acts in conflict herewith are hereby repealed.

Approved, March 19, 1918.

## DIAGRAMS SHOWING CONDITIONS AND EFFECTS OF THE DAYLIGHT-SAVING ACT.

By CHARLES F. MARVIN, Chief.

[Weather Bureau, Washington, Apr. 3, 1918.]

Charts XLVI–19 to XLVI–21 of this issue of the REVIEW show the hours of darkness and daylight, including twilight, for selected latitudes from 30° to 60° N., at intervals of 6°. The shaded blocks in the period of daylight show the ordinary hours of industrial labor as advanced and retarded by the operation of the daylight-saving act printed above.

The increasing number of daylight hours during the summer portion of the year for the more northern as compared with the southern latitudes, is a striking and significant feature of the diagrams. The corresponding shortness of daylight during the northern winters is also conspicuous.

The states and countries immediately adjacent to the selected latitudes are indicated on the diagram and the greater advantage resulting from the daylight-saving act, even in the countries north of the extreme northern boundary of the United States, is quite apparent.

It is important to remember that the diagrams are drawn on the basis of *mean solar time*. Accordingly, on the diagrams the hours of labor, etc., are depicted correctly with relation to local sunrise and sunset only for places whose geographic locations fall on or close to the standard meridian governing the time for any particular zone; that is, the diagrams may be assumed to represent true conditions on the 75th, 90th, and other standard-time meridians. However, since each zone comprises a full hour of difference of time, it necessarily results that the saving of daylight effected by the act is increased over that shown in the diagram for the more western portions of the zone up to half an hour, or thereabouts, and is correspondingly reduced in the eastern portions of each zone by an amount which becomes as great as half an hour, or thereabouts.

In connection with a study of the effects graphically set out in the diagrams, and a consideration of the grave doubts surrounding the chronology and history of events resulting from the arbitrary advancement and retardation of clocks involved in any scheme of this sort, it may be well to consider whether it would not ultimately be better, in the history of mankind, to arbitrarily advance the time of each zone a fixed amount—one-half hour or possibly one hour—which would remain the same throughout the year and continuously thereafter, thus seemingly more effectually avoiding the perpetual confusion in fixing the exact time of events that is hardly separable from the alternation between summer and winter. This scheme would always give to mankind the advantages of relatively longer daylight in the afternoons.

[1] The "mean astronomical time" here mentioned is understood to be the time called "mean solar time" by astronomers and meteorologists. It is determined by applying the "equation of time" to the sun's observed position.

These puzzling differences in the kinds of time are explained in "The American Ephemeris and Nautical Almanac for 1918," p. 713–714, and in Todd's "New Astronomy," Chapter VI.—C. A., jr.

## "SUMMER TIME" AND THE BRITISH METEOROLOGICAL OFFICE.

By Sir NAPIER SHAW.

[*From the* Twelfth Annual Report of the Meteorological Committee for the year ended 31st March, 1917 (sixty-second year of the Meteorological Office).]

Some addition to the work of the Divisions for Forecasts and Statistics was entailed by the adoption of "Summer-time" from May 21 until the end of September, 1916. The diurnal variations of weather are controlled by the sun, and for climatological purposes the fundamental principle of meteorological work is to note the conditions day by day at the same interval before or after true noon throughout the year. Local apparent time is therefore the proper time for observers to keep for climatological purposes; allowing a certain latitude, local mean time is prescribed in the books of instructions for climatological stations and suitable allowance can be made if Greenwich time is used; *but there is no means of dealing with observations which are an hour further from or nearer to noon in summer than in winter.*[1] As regards the Daily Weather Service, strenuous and very largely successful efforts have been made during the past 50 years to get the contributing stations of all countries of the region extending from Spitsbergen to Algeria and

[1] Italics ours.—EDITOR.

from the Azores to the Ural Mountains, to observe at the same point of time in spite of differences of longitude and consequently of local time, in order that there may be no dawdling in the central offices about the reception of the telegraphic reports. Into this international arrangement any change of practice in time keeping introduces confusion. For these reasons the Meteorological Office obtained permission under the [Summer-Time] act to retain Greenwich time for the hours of observation at its observatories and stations, but by doing so its reports were belated *nominally* by an hour and too late for the regular hours of delivery and postage. Special advance copies of an abbreviated report were manifolded and distributed. With the new hours at post-offices it became impossible to communicate the results of the evening observations except to privileged offices, and it was equally impossible to maintain the evening reports from the health resorts at the usual hour. They had to be made an hour earlier.[2]

Two points raised by the experience of Summer-time are brought out, added to other experiences of work for the war. One is of very general bearing, namely, the considerations that have led the associated countries to select a morning hour like 7h, G.M.T., for the chief meteorological effort of the day. It is not quite early enough for our [British] "evening" papers, and yet it is an uncomfortable hour in winter for office work. Now that the place of meteorological work in the life of the community is well established, the question might be reconsidered by the countries which are associated in meteorological work, after the war.

The other is of a more domestic character. The necessity for keeping the whole number of observers informed as to what action should be taken in regard to the change of clocks resolved itself into the need of regular opportunity of communication. Such communication is obviously a useful agency in the organization of a system which includes many hundreds of independent but cooperating observers distributed over the three kingdoms and associated only through the Office. In consequence, a four-page monthly circular has been set on foot for the purpose and has been found useful in many ways.[3]

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## "SUMMER TIME" OR DAYLIGHT SAVING IN OTHER COUNTRIES.

On another page appear quotations from the Annual Report of the Meteorological Committee of Great Britain setting forth the opinions and experience of the Meteorological Office during 1916–17 with "summer time" in Great Britain.

The British Secretary of State for the Home Department appointed, on September 20, 1916, a committee "to inquire into the social and economic results of the Summer Time act, 1916, and to consider (1) whether it is advisable that Summer Time should be reintroduced in 1917." This committee submitted its report on February 22, 1917 (London, 1917), and from a copy available at the central office the following extracts of special interest to the Weather Bureau are reprinted. The original numbering for the paragraphs has been retained.

### *Meteorological Work.*

**70.** The operation of Summer Time last year [1916–17] appears to have introduced some elements of uncertainty and difficulty into the work of the Meteorological Office. Sir Napier Shaw, the Director of the Office, supplied us with an interesting statement on the subject, the most important features of which we give below.

**71.** The work of the Meteorological Office, we are informed, has to be regarded from two points of view, viz:

(1) The *current daily work* of collecting information by telegraph from about 100 observatories and stations in the United Kingdom, on the Continent and the Atlantic Islands, and distributing reports, storm warnings, etc., based on this information, to various quarters; and

(2) The *public record*, which involves collection by the week or the month of (mostly voluntary) observations from 500 stations, in addition to the 100 official stations above mentioned.

**72.** The *current daily work* was continued at the same hours as previously, by Greenwich time, in accordance with the proviso in Section I (5) of the Summer-Time act. Consequently, as the messages from the stations were always telegraphed at the last possible moment before the closing of the post offices, the hour for sending them had to be changed, thus spoiling the continuity of the records.

Moreover the whole daily output of the office's reports, forecasts and storm warnings was nominally an hour late. So far as storm warnings are concerned the delay of an hour would have been fatal, since the country post offices were closed before the reports could be prepared and the hoisting stations could not therefore have been reached by telegraph.

No inconvenience, however, actually resulted in this respect in 1916 because, by request of the Admiralty, the general issue of warnings to coast stations had already been suspended on other grounds.

The distribution of the daily weather reports by early post (1:30 p. m. at the G. P. O.) had to be abandoned.

The opinion of the French Service was taken as to *the possibility of accelerating the whole service permanently* by an hour, but the proposal was not favorably received.

However, summing up the general effect of Summer Time on the current daily work, Sir Napier Shaw observes that "the inconveniences were as far as possible overcome without serious complaint from the services or the various naval and military establishments for which the information was collected."

**73.** As regards *the public record*, Sir Napier Shaw remarks that it is too soon to form an official opinion. In spite of very careful instructions a great deal of confusion arose with the observers as regards the hours at which the observations were made, and the continuity of many series of observations has been interrupted. "My impression is," he says, "that there is now no possibility of placing beyond dispute the exact time of any event, except those dealt with by telegraph, which occurred between May 21 and September 30. A future historian may find it impossible to fix the exact hour of the battle of Jutland. How many discontinuities, intentional or unintentional, there are in the records, will only be known when we summarize the results for the year, and

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[2] For an account of the organization of the Meteorological Office, see MONTHLY WEATHER REVIEW, 1915, **43**: 449, ffg.—C. A. jr.,

[3] *Great Britain. Meteorological Office Circular.* The attentive reader will have noticed several quotations from this circular in recent issues of the MONTHLY WEATHER REVIEW. The circular is of the page size of our own Bureau Topics and Personnel.

Beside the advices necessary for the cooperative observers and the various notes relating to Meteorological Office personnel, the circular usually contains several paragraphs on selected interesting current observations and frequently abstracts some publication of interest to the force. The value of the circular justifies a slightly higher grade of paper than that now employed, thereby insuring greater durability of the interesting records it carries.—C. A., jr.

how far they will affect the value of the results to be obtained from the observations will not be disclosed until we know what questions the services want us to answer. From the scientific point of view the discontinuity of hour introduces a defect which is fatal and for which there is no remedy."

**74.** Sir Napier Shaw concludes: "We have got through the immediate difficulties of Summer Time by making special provision of one sort or other to meet complaints addressed to us. For the future, if the experiment of 1916 is repeated, the proper course will be again to keep continuity as far as possible and make good the requirements of the service by whatever special provision we can devise and carry out."

**75.** We do not feel that we can add anything to Sir Napier Shaw's statement; but we may, perhaps, express the hope that the proposal for a permanent acceleration by one hour of the international service of weather reports (which we are told is not impossible to carry out, although it involves certain difficulties) will receive further consideration.

*Foreign countries.*

[The replies to circulars sent to foreign countries, and information supplied by the War Trade Intelligence Department, indicate that]—

**78.** Daylight-saving schemes were adopted last year [1916–17] by France, Holland, Denmark, Norway, Sweden, Italy, Portugal, and in Germany and Austria. The schemes were started on various dates from the 1st of May onward, and terminated for the most part at the end of September, the only exception apparently being in Portugal, where summer time was continued until the 31st of October. The variation from normal time seems to have been one hour in every case.

**79.** [According to the reports Great Britain (excluding Ireland), France, Holland, Portugal, Germany, and Austria, favored repeating the experiment in 1917; Denmark and Sweden were apparently undecided; Italy and Spain yielded no information.]

**83.** [Daylight-saving schemes have been adopted in Australia and Tasmania, and locally in Canada (Saint John, N. B.); New Zealand rejected the bill, and the Union of South Africa has not adopted a scheme.]

*Conclusion.*

**84.** We recommend, therefore, that Summer Time should be reintroduced in 1917 and in subsequent years.

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## RAINFALL OF 1917 IN THE BRITISH ISLES.

[*Reprinted from* Nature, London, Feb. 14, 1918, 100: 472.]

The rainfall of 1917 in the British Isles was about the average, but large areas of deficient rainfall occurred in all parts of the country. According to Symons's Meteorological Magazine for January (vol. lii, No. 624) the most important of these areas were in the center, part of the north, and the southwest of England, all of which had deficiencies of more than 10 per cent. The east midlands of Scotland were also dry, the deficiency exceeding 20 per cent over an area extending from the Firth of Forth to the Grampians. The southern half of Ireland and the extreme north and the south of Wales had a rainfall below the average. Unusually wet regions included the west and north of Scotland, the north of Ireland, the Yorkshire Wolds, Cardigan Bay, and the London district. August, October, and November showed a general excess of rainfall over the country. May was rather wet in Ireland and June in England, especially locally. February and December were unusually dry, and there was, on the whole, a general deficiency of rainfall during the first seven months of the year.

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## WEATHER AND HONEY PRODUCTION.[1]

By L. A. KENOYER.

[*Abstract reprinted* from U. S. Experiment Station Record, Washington, 1917, 37:854.]

The author here reports studies, based on daily records for 29 years, kept by a successful beekeeper, as to the weight of a hive of bees and the accompanying weather conditions. These show that changes in the weather exert a marked influence on the production of honey. The conclusions drawn are as follows:

"June yields 56 per cent of the annual hive increase and July about half of the remainder. A large June increase is indicative of a good honey year. There is an evident alternation between good and poor years. A good year has a rainfall slightly above the average, the honey season being preceded by a fall, winter, and spring with more than the average precipitation. A rainy May scarcely fails to precede a good honey season. South wind seems favorable and east wind unfavorable.

"The yield shows a gradual depression preceding and a gradual increase until about the fourth day following a rainy day, after which it remains fairly constant until about the fourteenth day following the rain. Good honey months average slightly higher in temperature than poor, this being especially true of the spring and fall months. Clear days are favorable to production of honey. Yield is best on days having a maximum of 80 to 90° F. and a wide daily range of temperature is favorable for a good yield. A low barometer is also favorable for good yield. The fluctuations in yield for a producing period seem to be closely correlated with the temperature range and the barometric pressure, acting jointly. A cold winter has no detrimental effect on the yield of the succeeding season, but a cold March reduces it. A winter of heavy snowfall is in the great majority of cases followed by a larger honey yield."

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## FORMER WEATHER BUREAU OFFICIAL IN NAVAL RESERVE FLYING CORPS.

A communication from the Office of Naval Operations, United States Navy, dated March 4, 1918, informs the Weather Bureau that former Professor of Meteorology and District Forecaster Alexander George McAdie, recently of Harvard University and Blue Hill Observatory, was enrolled in the Naval Reserve Flying Corps with the rank of lieutenant commander, on February 1, 1918, and is shortly to go abroad in connection with the meteorological branch of the Naval Air Service.

Lieutenant Commander McAdie's name is therefore to be added to the list of meteorologists given by Prof. R. De C. Ward, at the top of page 592 in the REVIEW, December, 1917. All who had the pleasure of an acquaintance with former Prof. McAdie will surely wish him great success in his new undertaking.

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[1] See Bulletin, Iowa State experiment station, 1917, **169**:15–26, fig.

## SECTION III.—FORECASTS.

### FORECASTS AND WARNINGS, FEBRUARY, 1918.

By ALFRED J. HENRY, Supervising Forecaster.

[Dated; Weather Bureau, Washington, Mar. 22, 1918.]

The severe weather of the winter 1917–18 came to a close temporarily in the Northwest on the 4th, the great interior valleys on the 5th, and Atlantic coast districts on the 6th. After about a week of moderate temperature a cold wave, the second of the month, moved across the country, beginning in the Northwest on the 13th and reaching Atlantic coast districts on the 16th. Another cold period set in on the 17th, reaching Atlantic coast districts on the 21st, and finally a short and less intense period began on the 24th and ended on the 26th.

Between these several cold periods the weather was warm—so warm, indeed, that nothwithstanding the great thickness of ice on the rivers and the heavy snow cover that was on the ground in the beginning of the month the ice went out of the streams, except the more northern ones, and the snow disappeared without causing severe floods in any part of the country.

East of the Rocky Mountains the weather of the month as a whole may be characterized as moderately dry, with periods of rapidly alternating temperature; west of the Continental Divide the month was wet, especially along the coast, with temperature close to the seasonal average.

#### PRESSURE OVER THE PACIFIC AND ALASKA.

Daily reports of pressure, temperature, wind, and weather were received from two points in the Pacific, Midway Island, north latitude 28° 13′, west longitude 177° 22′; and Honolulu, north latitude 21° 19′, west longitude 157° 52′. The stations reporting by cable or radio from Alaska number nine, most of which are coast stations, although the interior was represented by the station at Eagle, Alaska, north latitude 64° 46′, west longitude 141° 12′. Since the westernmost station in the United States proper does not exceed 125 degrees west longitude, it is seen that Alaskan reports give early information of the eastward march of weather conditions from the Pacific. These reports, in connection with those from the two points first named, continue to be of foremost interest to the forecaster.

The accidental pressure variations over the Pacific and over continental areas seem to be of different type: that is to say, the oceanic type as illustrated by Midway and Honolulu is different from the continental type in the following-named particulars: The oceanic type is more steady as measured by the less frequent occurrence of accidental changes and the greatly diminished amplitude of the variations. When these changes are portrayed graphically with time as ordinates and the variations above and below the normal as abscissæ, the resultant graph in the case of the oceanic type presents a smooth, well-rounded profile, while the graph representing continental areas presents a jagged, irregular outline.

Pressure at Midway was low on two occasions during the month, viz, from the 1st to the 4th and again from the 18th to the 24th, both inclusive. Pressure was high—that is, above normal—from the 4th to the 18th and from the 25th until the end of the month. The variations at Honolulu did not very closely parallel those just described, the most important variation being from the 14th to the 18th, when fairly high pressure prevailed at Midway, with the reverse conditions at Honolulu. It so happened that the lowest sea-level pressure of the month at Honolulu, 29.66 inches, on the 17th, occurred at a time when the pressure at Midway, as cabled, was 30.18 inches. Unfortunately reports from the southwestern islands of the Aleutian group for this date were missing; hence the supposition that the great area of high pressure, central over interior and the northwestern coastal region of Alaska, extended southwestward over the Pacific is more or less speculative. The Midway High seems to have advanced eastward, but the low pressure at Honolulu seems to have been coincident with a shallow depression that appeared off the Washington coast on the p. m. of the 16th. The track of this depression is platted as No. *VII*, Chart III. Two days after the occurrence of the barometric minimum at Honolulu a shallow depression appeared off the coast of north central California, where it remained 48 hours, and finally filled up. This depression appeared at a time when a strong anticyclone from Alaska was passing southeastward along the eastern slope of the Rocky Mountains. (See No. *V*, Chart II.) The combination—strong HIGH over northeastern Rocky Mountain slope, shallow LOW over California—is the ideal condition for winter rains in California, and much-needed rain fell on this occasion.

Finally, it may be remarked that pressure in Alaska was not uniformly high or low throughout the month, but that a period of low pressure especially well marked at Valdez, prevailed from the 1st to the 13th. During a part of this time, pressure was also low in interior Alaska. But beginning on the 12th, high pressure developed over Nome and spread southeastward, overspreading both coast and interior stations and endured without a break until the 20th. During this period of high pressure in Alaska two HIGHS, with the usual fall in temperature moved southeastward over the United States.

The most severe cold of the month occurred, however, at a time when pressure in Alaska had been unusually low for some days. The cumulative evidence of the month points to the conclusion that severe cold weather in the United States is not necessarily dependent upon high pressure and cold weather in Alaska as an antecedent condition.

#### HIGHS.

Eight principal HIGHS and three offshoots therefrom have been platted on Chart II.

The origin of these HIGHS may be placed, approximately at least, as follows: Four in western Manitoba, northwest of Lake Winnipeg; one in central Alberta; and three over the Pacific, west of the Oregon and north California coast. It is interesting to note that only two of the northwestern HIGHS occurred when pressure over Alaska was moderately high and that the remaining three occurred with either low pressure or nearly normal pressure over Alaska; also, that high area No. *I*, ap-

parently originated in west central Manitoba when pressure was low in Alaska. This HIGH caused a sharp drop in temperature and abnormal cold in its course to the east and south. The paths of the northern interior HIGHS was at first south and then eastsoutheast. The HIGHS which entered the continent from the Pacific, Nos. *III, VI,* and *VII,* moved generally in an easterly direction although they too have a slight southerly component of motion after crossing the Rocky Mountains. The northward loop in the path of No. *III* is probably due to the influence of local topography and elevation. The southeastward portion of the track probably represents the course of an offshoot from the original high in which central pressure increased from 30.36 inches on the coast to 30.74 inches at Yellowstone Park, Wyo., 48 hours later, and thereafter steadily diminished.

High area No. *V* showed the greatest pressure of the month, viz, 31.08 inches. This high level was reached wholly within the United States. On the morning of the 19th, the crest of the HIGH was 30.60 inches at Edmonton, Alberta. On the next morning it was in the upper Missouri Valley, covering parts of the three States, Montana, North and South Dakota, with central pressure of 31.00 inches and an average temperature of −30° F. The 24-hour rise in pressure over this area was a little more than 0.75 inch, or nearly double the rise at points in the Canadian Northwest. An explanation of this sharp rise in pressure over a considerable area when pressure was already at a high level would be exceedingly interesting and instructing. It does not seem likely that the weight of the column of air over the upper Missouri Valley could have been increased by the inflow of air from adjacent regions. If there had been such a flow, pressure would have fallen in the region from which the air was removed. Since no fall appeared within the field of observations, it would seem that the cause of the rise in pressure must be sought elsewhere. Prof. Humphreys has suggested that the flow of air southward in a HIGH, if vigorous, may so interfere with the normal eastward drift of the atmosphere as to cause a congestion or damming effect and thus produce higher pressure over the regions where the damming effect is most pronounced. The subject needs further observation and study.

### LOWS.

The paths of 10 primary and 4 secondary LOWS have been platted on Chart III. Six of these LOWS apparently originated in the Province of Alberta, three over the North Pacific west of Oregon and Washington and one near Lake Winnipeg, Manitoba. The paths followed by these LOWS—see Chart III—were closely in accord with previous experience. The speed of movement was unusually high. The tendency for a secondary LOW to develop to the southward and a little in the rear of the primary when the last named decreased in intensity was well illustrated during the month. LOW No. *III* appeared off the coast of Washington on the morning of the 6th. Evidently it divided during the day since on the night map two centers appeared, one in British Columbia with lowest pressure 29.10 inches, the other over southern Nevada with central pressure at 29.84 inches. The northern LOW moved rapidly eastward and disappeared beyond the field of observation toward Hudson Bay on the night of the 7th. Meanwhile the Nevada depression had crossed the Rocky Mountains, increasing in intensity and moved thence rapidly northeastward to Newfoundland as a moderately severe storm.

Again, LOW No. *IV,* appearing in the far Northwest, with central pressure of 29.60 inches, had developed into a long barometric trough by the forenoon of the 11th. A vigorous secondary appeared in the southwestern end of the trough and moved rapidly northeastward during the ensuing 48 hours.

North Pacific LOW No. *VII* appeared on the coast of Oregon on the 8 p. m. map of the 16th with central pressure 29.68 inches. This LOW advanced steadily and crossed the high mountains of Colorado on the 18th. On the 8 p. m. map of that date sealevel pressure at Pueblo, Colo., altitude 4,713 feet (1,436.5 meters), a station in the lee of the high Rockies immediately to the westward, was 29.24 inches and the temperature was 56° F., 18 degrees above the seasonal average. On the west side of the mountains as at Grand Junction, Colo., altitude 4,602 feet (1,403 meters), sealevel pressure was 29.28 inches and temperature 40° F., but 3 degrees above the seasonal average, with a south wind showing that the weather west of the mountains was still under the influence of the LOW. At the same hour a fairly strong anticyclone was moving southward along the eastern slope of the Rocky Mountains, its front being approximately 100 miles north of Pueblo, Colo. The temperature gradient between the center of the LOW and the southern front of the anticyclone was at least 0.3° F., per mile for a distance of probably 120 miles.

A pressure configuration as thus described can lead to but one result, viz, the elimination of the low center either partially or entirely and the formation of a new low center farther to the east or south. In this case a center of low pressure remained west of the mountains for 24 hours and eventually disappeared and a new center appeared as shown on Chart III, track No. *VII.* Further remarks on this formation will be submitted at a later date.

LOW No. *VIIIA* appeared on the morning of the 24th as a depression over Montana in the rear of primary LOW No. *VIII,* central at the time over Lake Superior with central pressure of 29.14 inches. This primary LOW passed rapidly eastward and pressure in the central region rose to 29.62 inches in 24 hours. In the meantime the secondary advancing as a long oval-shaped depression with two centers of low pressure, reached Lake Huron by the afternoon of the 25th with central pressure 28.80 inches attended by moderate southerly gales and thunderstorms in its southern portion and snow with northwest gales in the northern portion. The pressure continued to fall during the night as the storm passed down the St. Lawrence Valley. On the morning of the 26th, the barometer had fallen to 28.68 inches at Quebec. Fortunately this great depression of the barometer was not immediately followed by anticyclonic conditions and the temperature remained moderately high for the season after its passage.

The outstanding features of interest in connection with February LOWS are (1) the development of a secondary in each case, as the primary decreased in intensity, (2) the rapidity of movement of the LOWS, especially of the rain area in their eastern front.

### WARNINGS.

Storm warnings were issued for various parts of the Atlantic coast on February 3, 4, 8, 9, 12, 14, 19, 20, 25, and 26. The warnings of the 25th were for a whole gale from the Delaware Breakwater to Boston. Advices were also sent to open ports on Lake Michigan on the 3d, 13th, and 25th.

Cold-wave warnings were issued for various portions of the Washington forecast district on the 3d, 4th, 13th, 14th, 15th, 19th, and 20th, and special advices as to temperature conditions were issued on the 1st and 19th.

Two warnings of intensified northeast trades were issued for the Canal zone on the 4th and 19th, respectively. The following velocities were reached:

| | |
|---|---|
| Feb. 4 | 24 miles per hour, NE. |
| Feb. 5–6 | 26 miles per hour, NE. |
| Feb. 19 | 28 miles per hour, NE. |
| Feb. 20 | 26 miles per hour, NE. |
| Feb. 21 | 30 miles per hour, NE. |
| Feb. 22 | 27 miles per hour, NE. |

WARNINGS FROM OTHER DISTRICTS.

*Chicago, Ill., forecast district.*—The first cold wave warning of the month was issued for eastern Minnesota on the evening of the 2d, at which time an active disturbance of small extent was moving eastward over Minnesota, while an area of high pressure and low temperature was advancing southward over Manitoba. On the following morning the warnings were extended eastward over Wisconsin. These warnings were fully verified.

On the morning of the 13th a disturbance of marked intensity was central over Wyoming and an area of high pressure and low temperature was overspreading Manitoba and Saskatchewan. Cold-wave warnings were issued for North Dakota, northern Minnesota, and eastern Montana. During the afternoon and evening the warnings were extended southward over Wyoming and the Plains States and eastward over western Wisconsin, western and central Iowa, and northwestern Missouri. On the 14th warnings were issued for eastern Wisconsin and extreme eastern Iowa. Cattle warnings were issued for Wyoming and the Plains States on the 13th. These warnings were verified over the greater portion of these States.

Warnings were issued well in advance of the cold wave which overspread the greater portion of the district during the 18th–20th. The only warnings during the remainder of the month were those for North Dakota and portions of Montana, Minnesota, and South Dakota on the 24th. These warnings were only partially verified.—*Chas. L. Mitchell, Forecaster.*

*New Orleans, La., forecast district.*—Low temperatures attended an area of high pressure extending from the Plains States eastward over the Mississippi Valley and the Lake region on the 1st and the barometer being relatively low over Florida, cold-wave warnings were ordered for southeastern Louisiana. The cold did not reach southward to the Gulf coast. Another cold-wave warning ordered for southeastern Louisiana on the 3d was not verified because the pressure continued low in the west Gulf causing easterly winds to prevail.

An intense low-pressure area was centered over Kansas on the night of the 13th and the barometer was rising over the northwest; cold-wave warnings were ordered at 9:30 p. m. for Oklahoma, were repeated on the morning of the 14th and extended to northwestern Arkansas. Later in the day, the warnings were extended over Arkansas, northwest Louisiana, and northern Texas. The high pressure area and cold weather did not move as far south as was expected, and while a decided fall in temperature occurred, the verifying temperatures were not recorded except over the northern portion of the area covered by the warnings.

The a. m. weather map of the 15th showed an area of low pressure over the southeastern Rocky Mountain region and an intense high-pressure area over the British Northwest. Expecting the low-pressure area to move southeastward and under the anticyclonic area, cold-wave warnings were ordered on the 15th for the interior of Texas and on the 16th for Louisiana and the Texas coast. The low-pressure area moved southeastward as was anticipated and there was a decided fall in temperature but the warnings were only partially verified.

On the a. m. of the 18th, an area of low pressure was centered over Utah and an area of high pressure attended by low temperature was moving southward from the British Northwest. Cold-wave warnings were ordered for the Texas Panhandle, 9:40 a. m., advising live-stock interests that the temperature would be 10° to 16° on the morning of the 20th. Cold-wave warnings were issued at 9:45 a. m. on the 19th for Oklahoma, the Texas Panhandle and northwestern Arkansas, were extended in the afternoon and at night to the Gulf coast and repeated for the coast stations on the morning of the 20th. The warnings were fully verified over the interior of the district and partially verified on the coast.

Cold-wave warnings were ordered at 2:30 p. m. on the 27th for Oklahoma and northern Texas and repeated at night for Oklahoma. The temperature fell 30° to 40° but the warnings were only partially verified.

No cold waves or severe weather conditions occurred without warnings.

Southeast storm warnings were ordered for the west Gulf coast on the 27th and were verified on the Texas coast.

Fire-weather warnings were issued on a few dates for both Oklahoma and Arkansas and high winds occurred as forecast.—*I. M. Cline, District Forecaster.*

*Denver, Colo., forecast district.*—Cold-wave warnings were not required during the forepart of the month. On the morning of the 14th an extensive anticyclone occupied the Canadian Northwest, attended by temperatures close to zero in eastern Montana and North Dakota. Cold-wave warnings were issued for eastern Colorado, and repeated for the extreme eastern portion of that area in the evening as the pressure was still rising on the eastern slope. These warnings were only partially verified although temperatures as low as 6° to 10° above zero occurred in eastern Colorado on the 15th. On the 17th a North Pacific storm moved southward to southern Utah. On the morning of the 18th the barometer reading at Modena was 29.28 inches, and an anticyclone had moved into Montana from the Canadian Northwest. Cold-wave warnings were issued for northeastern Colorado. On the evening of the 18th the storm was over Colorado and the warnings were extended to include southeastern Colorado and northeastern New Mexico. The warnings were fully verified, except in the extreme western portion of northeastern New Mexico. The fall in temperature on the 19th was more than 30°, with zero temperatures in northeastern Colorado. During the night of the 18th–19th the storm divided, leaving an area of moderately low pressure in western Colorado. Meanwhile the anticyclone had been reinforced by high pressure from Alberta. Cold-wave warnings were repeated on the morning of the 19th for southeastern Colorado and extended to include all of eastern New Mexico. The warnings of the 19th were fully verified in the greater portion of eastern New Mexico and zero temperatures prevailed in portions of southeastern Colorado. Cold-wave warnings were also issued for eastern Colorado on the evening of the 24th. Although the temperatures were 20° to 30° lower in eastern Colo-

rado on the 25th they were not low enough to verify the warnings.

Warnings of strong winds were issued for considerable areas on the 6th, 7th, 13th, 17th, 18th, 24th, and 27th and were generally accurate, notably on the 13th and 14th when velocities of 40 miles per hour were reported in portions of New Mexico, 40 to 60 miles in Utah and 48 to 52 miles in Colorado; on the 18th when velocities of 52 miles occurred in southwestern Utah and 46 to 48 miles in New Mexico; and on the 27th when velocities of 30 to 64 miles were reached in New Mexico.

Freezing temperature was forecast for south-central Arizona on a few dates, and temperatures close to the freezing point occurred, except on the 9th when lower temperatures failed to accompany rising pressure.—*Frederick W. Brist, Assistant Forecaster.*

*San Francisco forecast district.*—February, 1918, in the Pacific States was not unusually stormy and transportation by sea and land suffered little interruption. During the last half of the month the long drought in California was broken by a rainy spell that lasted for a week or more, and the month closed with a drying "norther" that did no great harm, being of short duration.

There were many frosty mornings, but vegetation suffered little harm, as most crops were in a dormant state and those that were not dormant were for the most part protected by smudge fires or other means.

Storm warnings were ordered on 15 occasions at one or more stations; small craft warnings were ordered 4 times for limited stretches along the coast; live-stock warnings were sent to stockmen in Washington, Oregon and Idaho on the 4th, 6th, and 17th; and frost warnings were issued on 13 occasions to places in California. In addition to the general warnings of frost, special attention was given to a localized service for citrus fruit in the neighborhood of Pomona, Cal., where for the first time an attempt was made to foretell exact minimum temperatures about 12 hours ahead of their occurrence. This service was quite successful and sufficient data have been obtained this season to warrant the belief that more accurate minimum-temperature forecasts can be made for that locality next year.

The general frost forecasts were only partially successful and several frosts occurred without being predicted, due in nearly every case to a quick and unexpected clearing of the weather at about sunrise.

During the first half of the month gales were most frequent along the North Pacific coast, and during the last half most frequent along the California coast. Most of the storm warnings were fully verified, and only one for the coast of northwestern California, ordered on the 13th, was a complete failure. Small-craft warnings were justified in every case, and so far as known the live-stock warnings were timely and of value to stockmen.

Three notable failures occurred in the daily weather and temperature forecasts for northern California. Two of them were due to the retreat of a high pressure area off the southern California coast, which at the time the forecast was made seemed to be moving inland, in which case fair weather would ensue; but for some unknown reason a few hours after the morning reports were received these HIGHS retreated seaward far enough to permit northern California to come under the influence of low-pressure areas, and as a result considerable rain fell in the northern half of that State. (See a. m. charts Feb. 12–13.) The third failure was due to a low pressure area of marked intensity, the front edge of which was first noted on the morning of the 19th near Eureka. This storm before night caused general rains in California. Its subsequent movements were forecast with a fair degree of accuracy.—*E. A. Beals, District Forecaster.*

# SECTION IV.—RIVERS AND FLOODS.

## RIVERS AND FLOODS, FEBRUARY, 1918.

By ALFRED J. HENRY, Meteorologist.

[Dated: River and Flood Division, Mar. 29, 1918.]

The severity of the winter of 1917–18 was reflected in the thickness and extent of ice on all streams in the Ohio and upper Mississippi basins and to a less degree on the Missouri River and on streams in the Atlantic Drainage north of the James River of Virginia.

Abnormally cold weather set in in the first decade of December and continued almost uninterruptedly until February 5, 1918, when thawing weather overspread the Ohio Valley and Atlantic coast districts. During the last days of January moderately heavy rains fell over the southern tributaries of the Ohio as already described in this REVIEW, 46: p. 32, and in greater detail in the article on page 86 of this number of the REVIEW.

The weather during February, 1918, after the 5th, was made up of short warm spells separated by equally short intervals of rather severe cold, the night temperatures during nearly the whole month being so low as to check the rapidity of the run-off from the melting snow and moreover during the cold spells both day and night temperatures were low enough to hold in check the rising water in the principal rivers. On the whole there were very few floods in the ordinary sense but a great many flood stages were registered along the various streams by reason of ice gorges. The only rain floods of the month were experienced in the rivers of South Atlantic, East Gulf, and Pacific drainages and none of these were of exceptional character.

The details will be found in the tables below.

Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for chartering are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

TABLE 1.—*Flood stages in Atlantic drainage during February, 1918.*

| River and station. | Flood stage. | Above flood stages—dates. | | Crest. | |
|---|---|---|---|---|---|
| | | From— | To— | Stage. | Date. |
| *Hudson:* | *Feet.* | | | *Feet.* | |
| Albany, N. Y. | 12 | ..... | ..... | 11.5 | 21 |
| *Mohawk:* | | | | | |
| Tribeshill, N. Y. | 16 | 20 | 20 | 19.2 | 20 |
| Schenectady, N. Y. | 15 | 21 | 21 | 15.9 | 21 |
| *Delaware (East Branch):* | | | | | |
| Fishs Eddy, N. Y. | 10 | 20 | 20 | 16.0 | 20 |
| *Delaware (West Branch):* | | | | | |
| Hale Eddy, N. Y. | 12 | 20 | 20 | 13.4 | 20 |
| *Schuylkill:* | | | | | |
| Reading, Pa. | 12 | ..... | ..... | 11.3 | 20 |

TABLE 1.—*Flood stages in Atlantic drainage during February, 1918*—Continued.

| River and station. | Flood stage. | Above flood stages—dates. | | Crest. | |
|---|---|---|---|---|---|
| | | From— | To— | Stage. | Date. |
| *Susquehanna:* | *Feet.* | | | *Feet.* | |
| Oneonta, N. Y. | 12 | 20 | 20 | 14.0 | 20 |
| | | 26 | 26 | 12.9 | 26 |
| Bainbridge, N. Y. | 11 | 20 | 23 | 18.4 | 21 |
| | | 26 | (**) | 16.9 | 27 |
| Selingsgrove, Pa. | 17 | ..... | ..... | 15.5 | 21 |
| *Susquehanna (West Branch):* | | | | | |
| Clearfield, Pa. | 9 | 20 | 20 | 9.5 | 20 |
| Renovo, Pa. | 16 | ..... | ..... | 14.4 | 20 |
| Williamsport, Pa. | 20 | 20 | 20 | 21.4 | 20 |
| *Chenango:* | | | | | |
| Sherburne, N. Y. | 8 | 25 | (**) | 9.5 | 26-27 |
| *Potomac:* | | | | | |
| Cumberland, Md. | 8 | 20 | 20 | 9.0 | 20 |
| | | 26 | 26 | 9.0 | 26 |
| Washington, D. C. | 8 | 13 | 18 | 13.8 | 14 |
| *James:* | | | | | |
| Columbia, Va. | 18 | ..... | ..... | 17.3 | 14 |
| *Roanoke:* | | | | | |
| Weldon, N. C. | 30 | ..... | ..... | 28.6* | 1 |
| *Tar:* | | | | | |
| Rocky Mount, N. C. | 9 | ..... | ..... | 8.2 | 2 |
| Tarboro, N. C. | 18 | 4 | 4 | 18.3 | 4 |
| *Fishing Creek:* | | | | | |
| Enfield, N. C. | 14 | 1 | 3 | 16.0 | 3 |
| *Neuse:* | | | | | |
| Neuse, N. C. | 14 | (†) | 2 | 15.6 | 1 |
| Smithfield, N. C. | 13 | (†) | 4 | 17.0 | 1 |
| *Cape Fear:* | | | | | |
| Elizabethtown, N. C. | 22 | (†) | 4 | 27.2 | 2 |
| Fayetteville, N. C. | 35 | ..... | ..... | 34.4 | 1 |
| *Peedee:* | | | | | |
| Cheraw, S. C. | 27 | (†) | 1 | 30.0 | *31 |
| *Santee:* | | | | | |
| Rimini, S. C. | 12 | 1 | 11 | 16.2 | 5 |
| Ferguson, S. C. | 12 | 1 | 14 | 13.9 | 6 |
| *Wateree:* | | | | | |
| Camden, S. C. | 24 | (†) | 1 | 27.3 | *31 |
| *Saluda:* | | | | | |
| Chappell, S. C. | 14 | (†) | *31 | 14.5 | *31 |
| *Ocmulgee:* | | | | | |
| Abbeville, Ga. | 11 | 6 | 10 | 11.8 | 8 |

**Continued into March. *January.
†Continued from January.

TABLE 2.—*Flood stages in East Gulf drainage during February, 1918.*

| River and station. | Flood stage. | Above flood stages—dates. | | Crest. | |
|---|---|---|---|---|---|
| | | From— | To— | Stage. | Date. |
| *Alabama:* | *Feet.* | | | *Feet.* | |
| Selma, Ala. | 35 | 4 | 4 | 35.0 | 4 |
| *Coosa:* | | | | | |
| Gadsden, Ala. | 22 | 1 | 3 | 22.2 | 2 |
| Lock No. 4, Ala. | 17 | (†) | 4 | 18.8 | *31 |
| *Oostanaula:* | | | | | |
| Resaca, Ga. | 25 | ..... | ..... | 23.4 | 1 |
| *Tombigbee:* | | | | | |
| Demopolis, Ala. | 39 | 1 | 9 | 47.1 | 6 |
| *Black Warrior:* | | | | | |
| Tuscaloosa, Ala. | 46 | (†) | 2 | 53.9 | *31 |
| *West Pearl:* | | | | | |
| Pearl River, La. | 13 | ..... | ..... | 12.1 | 8 |

† Continued from January. * January.

TABLE 3.—*Flood stages in Great Lakes drainage during February, 1918.*

| River and station. | Flood stage. | Above flood stages—dates. | | Crest. | |
|---|---|---|---|---|---|
| | | From— | To— | Stage. | Date. |
| *Maumee:* | *Feet.* | | | *Feet.* | |
| Fort Wayne, Ind. | 15 | 13 | 18 | 20.5 | 15 |
| | | 20 | 21 | 17.0 | 20 |
| Napoleon, Ohio. | 10 | 14 | 17 | 19.5 | 14 |
| *Sandusky:* | | | | | |
| Upper Sandusky, Ohio. | 13 | 12 | 13 | 14.3 | 13 |
| Tiffin, Ohio. | 7 | | | 6.3 | 15 |
| Fremont, Ohio. | 10 | 14 | 14 | 11.0 | 14 |
| *Saginaw:* | | | | | |
| Saginaw, Mich. | 19 | | | 18.5 | 28 |
| *Shiawassee:* | | | | | |
| Owosso, Mich. | 8 | 16 | 21 | 8.6 | 18–20 |
| *Flint:* | | | | | |
| Fosters, Mich. | 18 | | | 17.9 | 20 |
| *Pine:* | | | | | |
| Alma, Mich. | 7 | | | 6.4 | 26 |
| *Chippewa:* | | | | | |
| Mount Pleasant, Mich. | 11 | | | 10.0 | 28 |
| *Grand:* | | | | | |
| Lansing, Mich. | 11 | 15 | 18 | 13.5 | 16 |
| | | 20 | 20 | 11.9 | 20 |
| Portland, Mich. | 12 | 7 | 9 | 12.4 | 8 |
| Ionia, Mich. | 21 | 16 | 18 | 21.6 | 17 |
| | | 20 | 23 | 22.0 | 20 |
| Eaton Rapids, Mich. | 6 | 14 | 24 | 7.9 | 15 |
| | | 26 | (**) | 7.0 | 28 |
| Grand Rapids, Mich. | 11 | 17 | (**) | 15.8 | 21 |

** Continued into March.

TABLE 4.—*Flood stages in Mississippi drainage during February, 1918.*

| River and station. | Flood stage. | Above flood stages—dates. | | Crest. | |
|---|---|---|---|---|---|
| | | From— | To— | Stage. | Date. |
| *Ohio:* | *Feet.* | | | *Feet.* | |
| Pittsburgh, Pa. | 22 | 21 | 21 | 27.1 | 21 |
| Davis Island Dam (Bellevue, Pa.). | 25 | 21 | 21 | 26.0 | 21 |
| Dam No. 2 (Coraopolis, Pa.). | 26 | 21 | 21 | 28.2 | 21 |
| Beaver Dam (Beaver, Pa.). | 30 | 21 | 22 | 37.6 | 21 |
| Dam No. 12 (near Wheeling, W. Va.). | 36 | 11 | 11 | 36.2 | 11 |
| Dam No. 13 (near Wheeling, W. Va.). | 43 | | | 39.8 | 22 |
| Marietta, Ohio. | 33 | 22 | 23 | 34.5 | 23 |
| Parkersburg, W. Va. | 36 | 22 | 22 | 36.0 | 22 |
| Dam No. 19 (near Tallman, W. Va.). | 39 | | | 36.3 | 23 |
| Dam No. 22 (near Ravenswood, W. Va.). | 42 | | | 38.8 | 23 |
| Point Pleasant, W. Va. | 40 | | | 38.7 | 23 |
| Portsmouth, Ohio. | 50 | | | 44.7 | 17 |
| Cincinnati, Ohio. | 50 | (†) | 6 | 61.0 | 2 |
| Do. | | 10 | 13 | 61.8 | 12 |
| Dam No. 37 (Fernbank, Ohio). | 50 | (†) | 5 | 57.3 | 2 |
| Do. | | 11 | 13 | 60.1 | 12 |
| Madison, Ind. | 46 | | | 44.7 | 13 |
| Louisville, Ky. | 28 | | | 26.7 | 14 |
| Cloverport, Ky. | 40 | 3 | 3 | 42.5 | 3 |
| Do. | | 15 | 17 | 42.0 | 15 |
| Henderson, Ky. | 33 | 4 | 4 | 33.1 | 4 |
| Do. | | 6 | 6 | 36.5 | 6 |
| Do. | | 13 | (**) | 37.8 | 16–18 |
| Mount Vernon, Ind. | 35 | 5 | 5 | 36.0 | 5 |
| Do. | | 14 | (**) | 39.0 | 18 |
| Evansville, Ind. | 35 | 4 | 7 | 38.0 | 6 |
| Do. | | 11 | (**) | 39.8 | 17 |
| Shawneetown, Ill. | 35 | 8 | 8 | 36.8 | 8 |
| Do. | | 14 | (**) | 40.2 | 25 |
| *Allegheny:* | | | | | |
| Warren, Pa. | 12 | 20 | 20 | 12.8 | 20 |
| Franklin, Pa. | 15 | | | 14.7 | 21 |
| Parkers Landing, Pa. | 18 | 20 | 20 | 18.5 | 20 |
| Mosgrove, Pa. | 20 | 21 | 21 | 20.5 | 21 |
| Freeport, Pa. | 22 | 20 | 21 | 25.8 | 20 |
| Dam No. 3 (Springdale, Pa). | 27 | 20 | 21 | 30.9 | 20 |
| Herrs Island Dam (Pittsburgh, Pa.). | 22 | 21 | 21 | 27.9 | 21 |
| *Clarion:* | | | | | |
| Clarion, Pa. | 12 | 20 | 20 | 14.9 | 20 |
| *Kiskiminetas:* | | | | | |
| Saltsburg, Pa. | 8 | 9 | 9 | 17.5 | 9 |
| Do. | | 13 | 13 | 8.0 | 13 |
| Do. | | 20 | 20 | 8.5 | 20 |
| *Stony Creek:* | | | | | |
| Johnstown, Pa. | 10 | 20 | 20 | ×11.7 | 20 |
| Do. | | 26 | 26 | ×10.8 | 26 |
| *Monongahela:* | | | | | |
| Fairmont, W. Va. | 25 | | | 23.2 | 26 |
| Greensboro, Pa. | 20 | 10 | 10 | 21.6 | 10 |
| Lock No. 4, Pa. | 31 | | | 29.7 | 21 |
| *Youghiogheny:* | | | | | |
| Confluence, Pa. | 10 | 12 | 12 | 13.6 | 12 |
| Do. | | 20 | 20 | 11.6 | 20 |
| Do. | | 26 | 26 | 10.5 | 26 |

† Continued from January. ** Continued into March.

TABLE 4.—*Flood stages in Mississippi drainage during February, 1918.*

| River and station. | Flood stage. | Above flood stages—dates. | | Crest. | |
|---|---|---|---|---|---|
| | | From— | To— | Stage. | Date. |
| *Beaver:* | *Feet.* | | | *Feet* | |
| Beaver Falls, Pa. | 11 | 20 | 20 | 11.1 | 20 |
| *Shenango:* | | | | | |
| Sharon, Pa. | 9 | 14 | 15 | 9.8 | 15 |
| Do. | | 20 | 21 | 9.9 | 20 |
| *Little Kanawha:* | | | | | |
| Glenville, W. Va. | 22 | | | 21.1 | 26 |
| *Muskingum:* | | | | | |
| Zanesville, Ohio. | 25 | 15 | 15 | 25.6 | 15 |
| McConnelsville, Ohio. | 22 | 14 | 16 | 24.9 | 15 |
| Beverly, Ohio. | 25 | | | 24.0 | 15 |
| Marietta, Ohio. | 32 | 16 | 17 | 32.4 | 17 |
| Do. | | 22 | 23 | 35.7 | 23 |
| *Tuscarawas:* | | | | | |
| Norris Point, Ohio. | 8 | 10 | 17 | 12.9 | 14 |
| Do. | | 20 | 22 | 11.2 | 21 |
| Coshocton, Ohio. | 8 | 12 | 16 | 13.2 | 13 |
| Do. | | 20 | 22 | 8.8 | 21 |
| *Walhonding:* | | | | | |
| Walhonding, Ohio. | 8 | 12 | 15 | 11.5 | 12 |
| Do. | | 20 | 21 | 10.4 | 20 |
| *Hocking:* | | | | | |
| Athens, Ohio. | 17 | | | 15.3 | 14 |
| *Scioto:* | | | | | |
| Larue, Ohio. | 11 | 12 | 13 | 12.0 | 13 |
| Bellpoint, Ohio. | 9 | | | 8.6 | 13 |
| Dublin, Ohio. | 8 | 12 | 12 | 11.5 | 12 |
| Circleville, Ohio. | 7 | 13 | 16 | 13.4 | 14 |
| Do. | | 20 | 21 | 10.4 | 21 |
| Chillicothe, Ohio. | 14 | 14 | 16 | 16.0 | 15 |
| *Licking:* | | | | | |
| Farmers, Ky. | 25 | 11 | 11 | 31.1 | 9 |
| Falmouth, Ky. | 28 | 9 | 9 | 28.1 | 9 |
| *Miami:* | | | | | |
| Tadmore, Ohio. | 12 | 12 | 13 | 13.0 | 13 |
| West Milton, Ohio. | 10 | 12 | 12 | 17.0 | 12 |
| *Kentucky:* | | | | | |
| High Bridge, Ky. | 30 | (†) | * 31 | 31.2 | *31 |
| Frankfort, Ky. | 31 | 1 | 1 | 32.3 | 1 |
| *Green:* | | | | | |
| Lock No. 6 (Brownsville, Ky.). | 30 | (†) | 1 | 30.1 | 1 |
| Lock No. 4 (Woodbury, Ky.). | 33 | (†) | 3 | 41.9 | 1 |
| Lock No. 2 (Rumsey, Ky.). | 34 | 5 | 7 | 34.9 | 6 |
| Do. | | 10 | 14 | 35.4 | 12–13 |
| *Wabash:* | | | | | |
| Bluffton, Ind. | 12 | 14 | 14 | 12.0 | 14 |
| Lafayette, Ind. | 11 | 12 | 18 | 21.6 | 14 |
| Do. | | 20 | 21 | 13.7 | 21 |
| Terre Haute, Ind. | 16 | 14 | 22 | 19.5 | 17 |
| Mount Carmel, Ill. | 15 | 13 | 27 | 21.0 | 21 |
| Vincennes, Ind. | 14 | 18 | 26 | 17.4 | 21–22 |
| *White:* | | | | | |
| Decker, Ind. | 18 | 17 | 21 | 19.6 | 20 |
| Elliston, Ind. | 19 | 12 | 17 | 22.2 | 12 |
| *Cumberland:* | | | | | |
| Celina, Tenn. | 45 | (†) | 4 | 55.2 | 1 |
| Carthage, Tenn. | 40 | (†) | 6 | 52.9 | 1 |
| Dover, Tenn. | 49 | (†) | 11 | 55.2 | 9 |
| Nashville, Tenn. | 40 | (†) | 9 | 49.9 | 5 |
| Lock A (Fox Bluff, Tenn.). | 43 | (†) | 9 | 47.0 | 6–7 |
| Clarksville, Tenn. | 46 | (†) | 10 | 51.8 | 7–8 |
| *Tennessee:* | | | | | |
| Knoxville, Tenn. | 12 | 1 | 1 | 15.0 | 1 |
| Johnsonville, Tenn. | 31 | | | 30.7 | 10 |
| Chattanooga, Tenn. | 33 | (†) | 3 | 42.5 | 2 |
| Bridgeport, Ala. | 24 | (†) | 4 | 28.5 | 3 |
| Guntersville, Ala. | 31 | 1 | 7 | 37.1 | 4 |
| Florence, Ala. | 18 | 1 | 8 | 21.8 | 6 |
| Riverton, Ala. | 32 | (†) | 10 | 42.0 | 7 |
| *Holston (North Fork):* | | | | | |
| Mendota, Va. | 8 | 28 | 29 | 14.0 | 29 |
| Do. | | 31 | (**) | 8.0 | 31 |
| *Clinch:* | | | | | |
| Clinton, Tenn. | 25 | (†) | 1 | 37.6 | *30 |
| *Illinois:* | | | | | |
| Morris, Ill. | 13 | 13 | 20 | 17.9 | 15 |
| Peru, Ill. | 14 | 13 | (**) | 21.8 | 16 |
| Henry, Ill. | 7 | 13 | (**) | 13.7 | 18–19 |
| Peoria, Ill. | 16 | 16 | (**) | 19.7 | 20 |
| Havana, Ill. | 14 | 19 | (**) | 15.2 | 24–27 |
| Beardstown, Ill. | 12 | 17 | (**) | 15.7 | 28 |
| Pearl, Ill. | 12 | | | 11.8 | 28 |
| *Mississippi:* | | | | | |
| Arkansas City, Ark. (Arkansas Basin.) | 42 | | | 39.0 | 28 |
| *White:* | | | | | |
| Clarendon, Ark. | 30 | | | 23.6 | 24–25 |
| *Black:* | | | | | |
| Black Rock, Ark. | 14 | 13 | 15 | 15.3 | 13 |
| *Cache:* | | | | | |
| Jelks, Ark. | 9 | | | 8.7 | 25–27 |

† Continued from January. * January.
** Continued into March. × Estimated.

TABLE 5.—*Flood stages in Pacific drainage during February, 1918.*

| River and station. | Flood stage. | Above flood stages—dates. | | Crest. | |
|---|---|---|---|---|---|
| | | From— | To— | Stage. | Date. |
| *Merced:* | *Feet.* | | | *Feet.* | |
| Merced Falls, Cal. | 7 | | | 6.5 | 24 |
| *Willamette:* | | | | | |
| Eugene, Oreg. | 10 | 7 | 7 | 11.5 | 7 |
| Oregon City, Oreg. | 10 | 7 | 10 | 12.2 | 8–9 |
| Portland, Oreg. | 15 | | | 13.8 | 8–9 |
| *Santiam:* | | | | | |
| Jefferson, Oreg. | 10 | 7 | 7 | 10.5 | 7 |

## ICE IN RIVERS, 1917–1918.

By ALFRED J. HENRY and others.

[Dated: River and Flood Division, Weather Bureau, Mar. 25, 1918.]

The severe and long-continued cold of the winter of 1917–18 caused heavy ice to form on northern rivers, as was to be expected, and pushed the southern limit of heavy ice a little farther south than usual.

Ice began to form on the Ohio as early as December and navigation on the upper and middle stretches of that stream was practically suspended by the middle of the month. The weather during January, 1918, continued unseasonably cold and there was practically no ice movement in any of the streams.

In December the ice in the Ohio had gorged at many places, the most extensive on the upper river being in the tortuous bends immediately above Sugar Creek, an insignificant stream that empties into the Ohio between Warsaw, Ky., and Rising Sun, Ind. (see fig. 1.). A second extensive gorge formed in the vicinity of Evansville, Ind.

The termination of the cold weather came in the closing days of January when a day or so of thawing weather with rain was the occasion of a break-up of the ice in the southern tributaries of the Ohio, the ice passing into the trunk stream on fairly high stages. Short periods of cold weather with night temperatures considerably below freezing were the rule until about February 5, when a decided rise in temperature set in over the Ohio Valley and mild temperatures for the season continued for nearly 10 days.

The most serious gorge in the Ohio, as above stated, was the one that formed above Sugar Creek between Cincinnati and Louisville. Fortunately this gorge did not wholly prevent the flow of water beneath it and as a consequence the channel below the gorge was open and the river was at a comparatively low stage when the gorge finally broke on February 12, after holding firm for 58 days. The history of this gorge is fully set forth in the report of Meteorologist W. C. Devereaux, in charge of the Cincinnati district, page 86.

Recognizing the importance of preserving an account of the ice blockade along the Ohio and Mississippi, the following details are presented by the Weather Bureau officials in charge of respective districts, Pittsburgh, Pa., to Cairo, Ill., on the Ohio and St. Paul, Minn., to Vicksburg, Miss., on the Mississippi.

### MISSISSIPPI DRAINAGE.

#### OHIO RIVER.

*Pittsburgh, Pa., river district.*

Low temperatures set in on December 1 and continued almost uninterruptedly to February 5, a period of 67 days, with only 6 days when the temperature was above the normal. The accumulated deficiency for December was 317°; for January, 268°; and for the 5 days in February, 88°; or a total deficiency of 673°. The accumulation of snow on the ground ranged from 5 to 10 inches over the Monongahela watershed and from 10 to 30 inches over the Allegheny watershed. Ice formed in the rivers from 1 foot to nearly 3 feet in thickness.

Moderately heavy rains in West Virginia, together with higher temperatures on January 27 to 29, melted most of the snow in the Monongahela Valley, causing a break-up in the Monongahela River. The ice formed an immense gorge below Morgantown and another near Brownsville, the water backing up over the Baltimore & Ohio Railroad tracks at Morgantown, with a stage of 39 feet at Lock No. 10, and 25 feet at Fairmont at 2 p. m. of January 29. The gorge at Brownsville backed up the water over the low ground of that place and shut down many mines in that vicinity, reaching a stage of 21.6 at Greensboro, Pa., on February 10. As the ice in gorge formation moved along it carried away and sunk quite a number of barges and three steamboats. Ice also gorged in the Ohio River near Steubenville, Ohio, and below Wheeling, W. Va., backing up the water at Wheeling to 37.8 feet on February 11. A portion of the ice from the Kiskiminetas lodged in the Allegheny River below Freeport, Pa., but the Allegheny remained frozen throughout.

After the thaw in the latter part of January another period of cold weather set in, with more snow, and the Monongahela again froze over with new ice. Higher temperatures and moderate rains on February 19 caused a break-up in the ice in the Monongahela. The gorges at Morgantown and Brownsville broke up, the ice floated a short distance and disappeared, probably sinking from the weight of sand and mud. None of this ice reached Pittsburgh. The Allegheny ice broke up, beginning in the lower river, and coming out in patches to above Warren, Pa. A gorge formed below Corydon, Pa., a short distance above Warren, backing the water over the town of Corydon, and causing much damage. The gorges in the Ohio also moved out on February 19.

Reports at 8 a. m. of Wednesday, February 20, showed that heavy rain had occurred throughout the watersheds of the Allegheny and Monongahela Rivers, with high temperatures melting the snow and ice in the mountains, causing rapid rises in all streams. At 10 a. m. a flood warning was issued for a stage of 28 feet at Pittsburgh by the next morning. After further reports were received the stage for Pittsburgh was reduced to 27 feet, and a warning issued for 37.5 feet at Wheeling Thursday night. The crest of the flood passed Pittsburgh at 6 a. m. on Thursday, the 21st, with a stage of 27.1 feet, and Wheeling at midnight, Thursday, with a stage of 37.9 feet.

Never before have the conditions as to the accumulated depth of snow on the ground and the heavy formation of ice in the rivers assumed such threatening and dangerous character. The water equivalent of the snow on the ground ranged from about 1 inch over the Monongahela Valley; about 2 inches over the Youghiogheny; and from 2 to 3.50 inches over the Allegheny Valley. Owing to the small amount of rain during January and during the first part of February, and with rising temperatures after February 5, the snow gradually became less and the ice more or less rotten and honeycombed. The ice all moved out of the Youghiogheny without loss, as did also the ice in the Allegheny, with the exception of the gorge formation near Corydon. The destruction of the property along the Monongahela was caused by immense ice gorges with moderate stages of water. The flood of February 20–21 was caused by heavy rain and melting snow; it passed without material loss, and completely cleared all streams of ice.

The direct loss to property due to ice gorges as estimated was one coal tipple destroyed; five tipples damaged; three steamers sunk—but salvaged—and about 20 coal flats sunk. A great loss was entailed by suspension of mining and shipping of coal. Many mines were closed by high water and owing to railroad congestion the shipment of coal was curtailed very little, being shipped by water for several weeks.

SUMMARY OF ESTIMATED LOSSES.

| | |
|---|---|
| Money loss due to destruction of property | $100,000 |
| Money loss due to suspension of business | 200,000 |
| Money saved by warnings | 500,000 |

—*Henry Pennywitt, Meteorologist in Charge.*

*Parkersburg, W. Va., river district.*

A gorge formed on January 31, 1918, 8 miles below Dam 14, Ohio River, extending 20 miles down the river. This gorge went out at 5.30 a. m., February 11, breaking at a stage of 35 feet. The thickness of the gorge was about 12 feet. Resulting damage, about $1,500.

At Dam 15, Ohio River, the gorge moved at 5 a. m., February 11, and gorged again 3 miles below the dam, when the river at the dam rose from 15 feet to 26.6 feet. The gorge broke again at 2:20 p. m. the same day, and the river was clear at 4 p. m. The thickness of the gorge was about 12 feet. Resulting damage was about $1,500.

Packed ice formed in the Ohio from Dam 19, Ohio River, to Parkersburg, a distance of about 7 miles, on January 12, 1918, and held until 6:10 p. m., February 9, when a movement of 600 feet took place, with a stage of 17 feet at Dam 19. No damage resulted. The ice moved again at 6 a. m., February 10, with a stage of 23 feet at Dam 19, and

wrecked both steel light towers on the lock wall of Dam 19. There was no ice gorge with the movement. Resulting damage, about $600.

On December 22, 1917, a gorge formed at the foot of Buffington Island, about 5 miles above Dam 22, Ohio River, and moved out on February 10, 1918. This was a small gorge, probably about 5 feet in thickness. No damage resulted.

Early in January, 1918, an ice gorge formed about 5 miles above Middleport, Ohio. This gorge went out on February 10, without doing damage. This was also a small gorge, probably about 5 feet in thickness.

Early in January another small gorge formed 7 miles below Middleport, Ohio. This gorge also went out on February 10, without doing damage.

On January 29 a gorge formed at Nicolette on the Little Kanawha River, extending up the river about 15 miles, with a thickness of 10 feet. This gorge did not go out, but melted and sank, causing no damage.

On January 29 the ice went out of the Little Kanawha River below Dam 1. This ice movement caused an approximate loss of $1,500 to river craft at Parkersburg.

Approximate total loss from ice gorges, $6,600; from other ice movements in the district, $3,000.—*Henry C. Howe, Meteorologist in Charge.*

## *Cincinnati, Ohio, river district.*

*Air temperatures and ice conditions.*—The temperature over the Cincinnati district during the late fall of 1917 was unseasonably low, and specially so during the last 10 days of November when it was considerably below freezing nearly every day. The river stages were low and the water was cold when the severe cold wave of December 8 swept over the Ohio Valley. The temperature at Cincinnati fell to 2° below zero on that day, and the weather continued very cold with temperature near zero during the following nine days.

Light ice formed in the Ohio River and its tributaries during the night of December 8–9, and the tributaries froze over at many places during December 9 and 10. In the Ohio ice continued to form so rapidly that practically all navigation had been suspended by the morning of the 10th. During that night the river gorged at Fernbank Dam, about 13 miles below the Cincinnati gage, due partly to the obstruction offered by the wickets which had not been lowered. This gorge extended to the Cincinnati gage and a few miles above on the morning of December 12. The wickets at the dam were lowered on the 11th but the ice did not move between Cincinnati and Fernbank until the afternoon of the 12th. On December 13, 14, and 15, the ice in the Ohio became heavier but continued to move, except occasionally at the sharp bends in the river where temporary gorges formed. At 3 a. m. December 16 a permanent gorge was formed at Dam No. 39, a short distance above the mouth of the Kentucky River. Although there were movements in the ice at different times in other portions of the rivers in the Cincinnati district, the gorge formed in the sharp bends of the river above Dam No. 39, and later known as Sugar Creek gorge, held firm from December 16, 1917, to February 12, 1918.

Except for a few mild days from December 19 to 24, the weather continued very cold, and the two-months period of severe cold, from December 8, 1917, to February 7, 1918, was the longest on record for the Ohio Valley. At Cincinnati the temperature was below zero on 16 days and only slightly above zero on several other days. The lowest during December was 13° below zero and during January 16° below zero, both of which are the lowest of record for the respective months. Along the lower stretches of the river the weather was even colder than at Cincinnati. At Vevay, Ind., five miles below Dam No. 39, the temperature was below zero on 22 days, the lowest for December being 20° below zero and for January 24° below zero.

The ice gorges in the Ohio River in this district formed in the lower part of the river and gradaully extended up the river with the advance of the season. The first permanent stops of the ice at the various points, beginning at the lower end of the district, were as follows:

Ice stopped at Dam No. 39 at 3 a. m., December 16, 1917.
Ice stopped at North Bend during the night of December 16–17.
Ice stopped at Cincinnati at 3 p. m., December 17, 1917.
Ice stopped at Maysville at 3:10 p. m., January 1, 1918.
Ice stopped at Portsmouth at 4:30 p. m., January 3, 1918.
Ice stopped at Dam No. 29 at 12:10 p. m., January 12, 1918.
Ice stopped at Dam No. 28 at 8 p. m., January 12, 1918.
Ice stopped at Dam No. 26 about noon, January 13, 1918.
Ice stopped at Gallipolis at 4:30 p. m., January 13, 1918.
Ice stopped at mouth of Kanawha during the night of January 19–20, 1918.

On December 17, 1917, gorges in the Ohio above the mouth of the Kanawha cut off the supply of moving ice from above and the few days of mild weather beginning on December 18 prevented the formation of new ice. New ice began forming again on December 26, and considerable ice came out of the upper Ohio during the last five days of December. The gorges then gradually extended up to near the mouth of the Big Sandy. Rain, with temperature slightly above freezing, over the southern tributaries on the afternoon of January 5 and during the 6th caused a slight rise in the river and again delayed the growth of the gorges, but heavy ice continued in the Ohio between the mouth of the Kanawha and the mouth of the Big Sandy. With the occurrence of the coldest weather on record for January, on the 12th, gorges formed rapidly at Dams Nos. 29, 28, and 26, and at Gallipolis. Due to both rivers freezing over above Point Pleasant and cutting off the supply of moving ice, and the cross-currents, the river did not freeze over at the mouth of the Kanawha until the night of January 19–20. This was the first time that the Ohio River had been frozen over at the mouth of the Kanawha in 23 years.

Practically all rivers in the district were frozen over from January 20 to 27, 1918. The ice was very hard, due to the continued cold weather. The height of the water gradually rose from about 12 feet to about 22 feet from Cincinnati to the mouth of the Kentucky between the middle of December and January 27. There was traffic on the frozen river, and at several places heavy loads crossed on the ice with horses and on automobiles.

*Floods in southern tributaries.*—On the afternoon of January 26, 1918, moderate rains fell over the headwaters of the southern tributaries and these streams began rising, and the ice broke in the Tug and Levisa Forks of the Big Sandy River. During the night of the 27th–28th another storm caused heavy and general rains over the valleys south of the Ohio River. On the morning of the 28th the Kanawha-New, Guyandotte and Big Sandy Rivers were rising rapidly and the ice had broken. These rivers continued to rise rapidly during the 28th, and the following crest stages, which are the highest on record, were reached: Logan on the Guyandotte, 27 feet at 1 p. m., 28th; Williamson on the Tug Fork of the Big Sandy, 38.3 feet about midnight of the 28th–29th; and Pikeville on the Levisa Fork of the Big Sandy, 50 feet at 9 p. m. on the 28th. The crest stage at Pikeville was 9 feet above the previous high-water record. The crest at Louisa on the Big Sandy was 47 feet, or 1.3 feet below the high-water record. The crests were below the flood stages at all places in the Kanawha Valley. The Licking River rose considerably and the ice broke at Farmers, Ky., on the North Fork, but the ice did not break in the Licking itself or in the South Fork.

*Rise and breaking of gorges in the Ohio.*—The rise in the Ohio River below the mouths of the Kanawha, Guyandotte and Big Sandy Rivers, began during the forenoon of the 28th, and after the river had risen about 12 feet the ice began to break. Because of the more rapid discharge of the Big Sandy the ice began breaking first at the mouth of that river. In the Big Sandy, 3 miles above the mouth, the ice started moving at 8 a. m. of the 28th and by noon most of the ice had passed into the Ohio where it piled several feet high over the banks. At Dam No. 29, 3 miles below the mouth of the Big Sandy River, the ice started moving slowly at 12:55 p. m., the same day.

At the mouth of the Kanawha the ice started moving into the Ohio at 3 p. m. on the 28th, and after a short time an open space appeared in the center of the Ohio in which a distinct whirl in the water was visible. The ice around this whirl gradually broke up, and the ice from the Kanawha gorged both up and down the Ohio and piled high on the opposite bank. At Gallipolis, 4 miles below the mouth of the Kanawha, the ice did not break until 9:40 p. m. that night, and at Dam No. 26, 9 miles farther down, the ice broke about midnight. The following morning at 5:40 it broke at Dam No. 28, 6 miles below the Guyandotte and 7 miles above the Big Sandy.

At 7 a. m. on January 29 the ice was moving from the mouth of the Kanawha nearly as far down as Portsmouth. The river above Portsmouth was about 15 feet higher than below. At Portsmouth the ice moved for one minute at 5:15 a. m., but the general movement did not start until 9:30 a. m. Ten minutes later the ice broke at Dam No. 31, 3 miles down the river, and at Buena Vista, 22 miles below Portsmouth, two hours later. During the afternoon of the 29th the ice jammed between Portsmouth and Maysville, causing an artificial rise of about 10 feet in the river at Portsmouth, where the ice stopped running from 4:15 p. m. to 5:20 p. m. The crest stage at Portsmouth was 49.5 feet.

At Maysville the ice broke at 11:20 p. m. of the 29th, and the breaks apparently moved down the river quite steadily during the night, reaching Coney Island at the upper end of Cincinnati at 7 a. m. on the 30th.

At Cincinnati the river began rising rapidly shortly after 7 a. m. January 30, and at a stage of about 28 feet the ice broke at 10 a. m. The river rose 7.5 feet in the next hour and the ice was moving at the rate of about 6 miles per hour. The ice began moving at Fernbank Dam, 14 miles below the Cincinnati gauge, at 11:15 a. m., and after moving slowly for 30 minutes it stopped and gorged during the afternoon as far up as Coney Island. That night the gorge broke at Cincinnati at 11 p. m., and the ice started moving rapidly past Fernbank at 11:45 p. m. This break carried the ice through the heavy gorge at North Bend and past Lawrenceburg and Aurora. Boats and barges which were carried out of the Cincinnati Harbor were held in the ice just below Rising Sun, Ind.

As soon as the first big rise in the river had passed the ice began to jam in the sharp bend in the river at North Bend, Ohio, and a

new gorge was formed which extended up to Cincinnati. The ice at Fernbank Dam within this gorge stopped moving at 10:03 a. m. January 31. Logs and other débris from the Big Sandy Valley were held in the ice at Fernbank Dam, and boats from the Kanawha Valley were held in the ice a few miles farther up the river.

*Sugar Creek gorge.*—The big gorge between Rising Sun and Dam No. 39 was the only one that held firm during the entire rise. This became known as Sugar Creek gorge, although it was later discovered that the foot of the gorge was 1 mile above Sugar Creek. The gorge proper was located in the sharp bends in the river extending from North Landing, 3 miles below Rising Sun, to the first bend in the river below Patriot, Ind., a distance of 12 miles. This portion of the river opposite side of the river, with deep valleys cutting through the steep banks at many points.

The first point where the ice began to hold was in the bend at North Landing. Here the top of the bank on the outside of the bend is within 200 feet of the low-water line. Two small valleys break through the bank within a distance of 2 miles, and a portion of the ice moved up these valleys. At two places highway bridges were pushed upstream by the ice, and a fair-sized steel bridge was crushed with the pressure of the ice over the banks. The topography of the banks at other places within the gorge, especially between Gunpowder Bar and Big Bone Island, and between Patriot and Sugar Creek, is favorable for holding the ice.

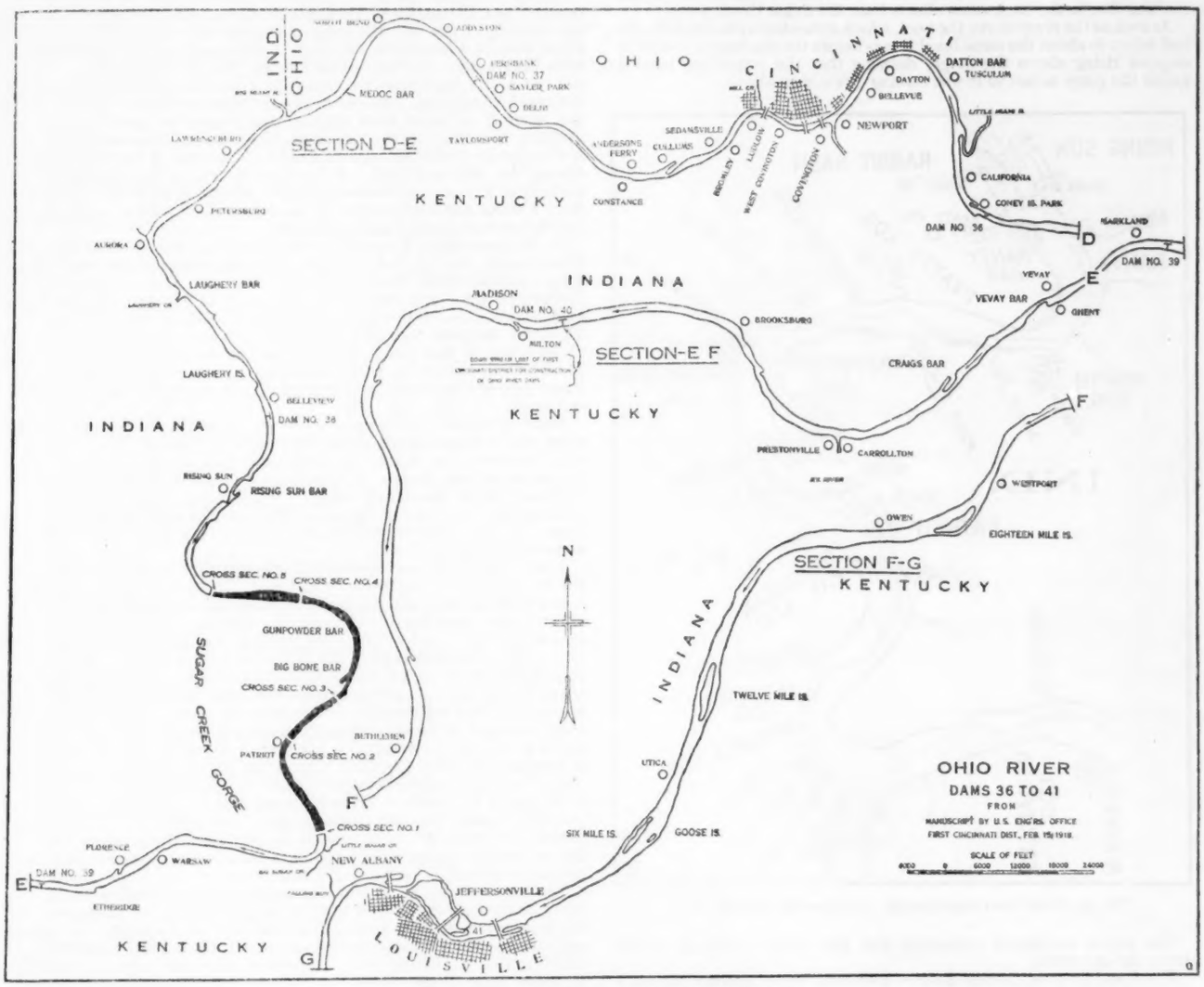



Fig. 1.—Ohio River, Cincinnati, Ohio, to Louisville, Ky.

Portion affected by Sugar Creek gorge is drawn in solid, and shown in detail on Fig. 1a. Cross sections 1 to 5 of Fig. 2 are indicated here by white bars.

is very crooked with irregular banks which project in and form sharp angles. (See fig. 1.) There is one large bar known as Gunpowder Bar, and a short distance below is Big Bone Island, but it is believed the steep and irregular banks and sharp bends were greater factors in holding the gorge than the irregularities in the bed of the river.

Very few portions of the Ohio River show so many sharp bends within a distance of 12 or 15 miles as that portion above Sugar Creek known as the "Ox-bow." From above Rising Sun to below Sugar Creek the river has somewhat the shape of two letters S attached end to end. As shown by the cross sections of the river (fig. 2) the center of the channel is first on one side and then on the other, and at one point the bank is steep and high on one side only, while a few hundred feet farther down the river the nearly perpendicular bank is on the

Much of the ice which had covered the river for a distance of 40 miles above North Landing (see fig. 4) was jammed into the first 10 miles of the gorge, forming great hills of ice, some of which were 30 feet or more high, and pushing far up the valleys and ravines and over the lower portions of the banks. For 2 miles upstream from the foot of the gorge the ice remained smooth, except for a split of crushed ice about 20 feet wide and probably extending to the bottom of the ice. This split started in the center of the channel and extended down to the end of the gorge, being somewhat nearest to the left bank looking upstream. At Patriot, about 3 miles above the foot of the gorge, the ice broke in the middle of the river and pushed out against the banks, turning up great cakes of ice, one of which was nearly vertical and rose 20 feet above the surface. At this point there were also large fields of unbroken

ice. From Patriot up to North Landing both the ice cakes and fields of unbroken ice gradually decreased in size until the fields disappeared, and there remained only a conglomerate mass of crushed ice at the head of the gorge.

This gorge continued to back up the water until the river reached a crest stage of about 58 feet at Rising Sun, Ind., on the morning of February 3. The level of the water then was about 25 feet higher above the gorge than below it. At that time there was a nearly level pool of water extending 104 miles up the river as far as Dam No. 33 above Maysville. Gorged ice covered the river from North Landing to Aurora, and also from North Bend to Cincinnati, but these gorges had but little effect on the flow of the water. The crest at Cincinnati was 61.2 feet at 2 a. m. February 2, 1918. Between 15 and 20 feet of this rise was due to the backwater effects from the Sugar Creek gorge.

As soon as the river above the pool, which extended up to Dam No. 33, had fallen to about the same level it was before the rise began, the river stopped rising above the gorge, showing that the water was passing under the gorge as fast as it was coming down from above.

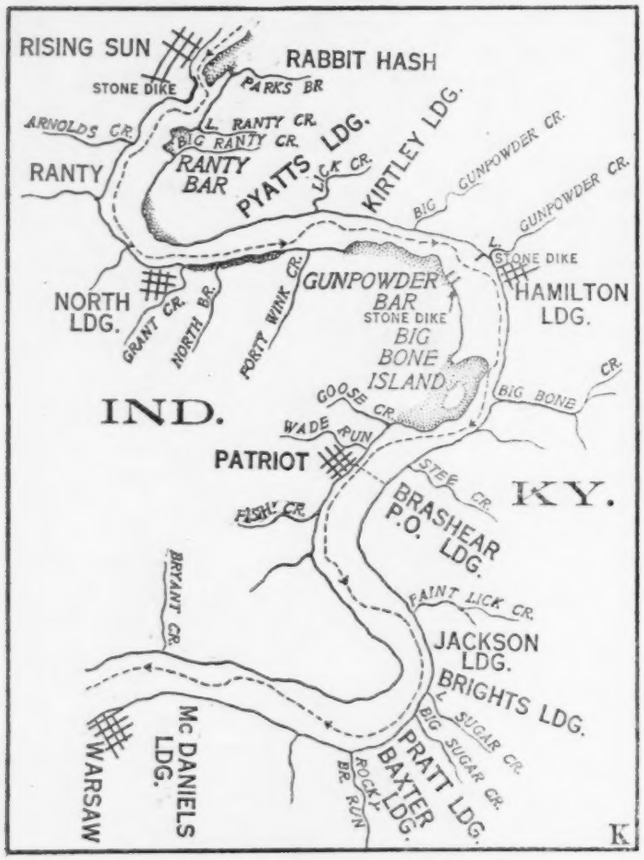



Fig. 1a.—Sugar Creek bend enlarged. (Compare fig. 1 and fig. 2.)

The gorges continued stationary and the river continued to fall slowly for one week.

*Flood and gorge in Licking River.*—Rain and warm weather caused a rise in the Licking River on February 9, 1918. Ice broke at 5 a. m. in the South Fork at Cynthiana, Ky., and the river rose rapidly to near flood stage, and the ice broke in the North Fork at Farmers, Ky., at 1:30 p. m. Both of these tributaries brought considerable water and a large amount of ice into the Licking and a big gorge was formed in that river just below Butler, Ky., about 17 miles below Falmouth. The water backed up as far as Falmouth where the crest stage was just above the flood stage of 28 feet. On the morning of February 10 the water at Butler was much higher than ever known before and the stage was estimated to be 55 feet. This made a very threatening condition for Cincinnati, as a break in the Licking gorge would cause a sudden rise of probably 10 feet or more, and the Ohio River was nearly full at the time. During February 10 and 11 the flood water in the Licking came out slowly under the ice and most of the ice was left in the river. The gorge below Butler moved about 500 feet during the early morning of the 11th, and moved again at 8:40 a. m., but the ice jammed in the bends below and did not reach the mouth of the river at that time.

The gradual decrease of the slope in the Licking, the backwater from the Ohio, and the sharp bends and irregular banks below Butler, prevented the ice from coming out of the Licking. The average slope of low water from Falmouth to Butler, 17 miles, is 2 feet per mile, and for the 35 miles from Butler to the mouth it is 1¼ feet per mile. On the morning of February 10, when the crest stage occurred at Butler, the elevation of the water in the Ohio at the mouth of the Licking was practically the same as the elevation of low water at Butler. At this time the high water at Butler was about 55 feet higher than the water in the Ohio, and the average slope was less than 2 feet per mile. By the evening of February 11 most of the water was out of the Licking, except the backwater from the Ohio.

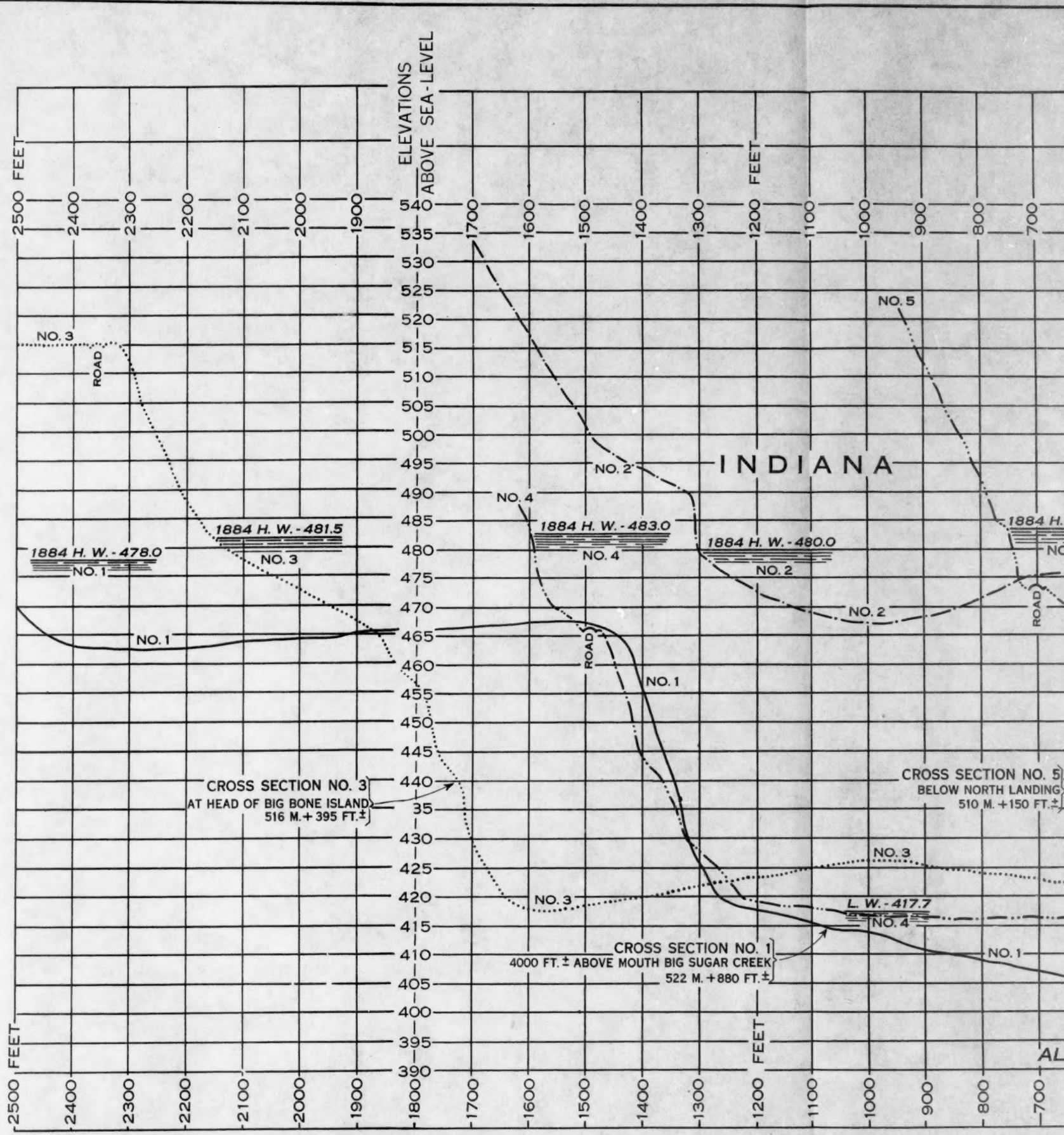
*Second backwater rise at Cincinnati.*—A second rise in the river between Point Pleasant and Portsmouth started on February 9, and by the morning of the 10th the stage at Portsmouth was 23 feet, or 27 feet lower than at Cincinnati, although Portsmouth is 113 miles upriver from Cincinnati. As the current in the Ohio at Cincinnati was very slow for such a high stage the first part of the rise from Portsmouth did not reach Cincinnati until the night of February 10–11. At this time the amount of water from the Licking began to decrease but this decrease was offset by the rise from above in the Ohio, so that the rise at Cincinnati continued almost steady at the rate of 0.2 feet per hour during the 10th and 11th. A careful estimate of the velocity of the current at 2 p. m. on February 11 at Cincinnati showed it to be less than 2 miles per hour, while the average velocity for a stage near 60 feet is between 6 and 7 miles per hour.

On the morning of February 12 the river stage was about 60 feet from Cincinnati to Aurora, Ind., and the backwater effect of the Sugar Creek gorge extended from North Landing to Dam No. 33 above Maysville, a distance of more than 100 miles. The stage at Portsmouth, above the pool, was 23.2 feet lower than at Cincinnati, and the stage at Dam No. 39, below the gorge, was 29.4 feet lower than at Aurora. The river was rising above at this time. On February 3, when the river was falling at all places above the gorge, the stage at Portsmouth was 32.1 feet lower than at Cincinnati, and at Dam No. 39 it was 26.2 feet lower than at Aurora.

*Break of Sugar Creek gorge.*—From the time the ice jammed in the river above Sugar Creek during the night of January 31–February 1 until February 12 there was very little change in the gorge. The temperature was mostly above freezing after February 6, and on February 11 the maximum was 57°, but this comparatively high temperature had very little apparent effect on the very hard ice in the gorge. Even on the surface the ice melted very little, but did loosen somewhat along the banks.

About 8:40 a. m. on February 12 the ice broke a mile below Dam No. 39, 4 miles upriver from Vevay, Ind., and moved down the river. A few minutes later the ice began to bulge up in front of the dam and water began spurting up through the cracks. The ice next began moving in the center of the river, very slowly at first, but gradually increased in velocity during the forenoon with a rapidly rising river. Practically all of the ice had passed out below the gorge leaving open water free of ice. The strong wind and high temperature during the forenoon helped considerably in breaking the gorge. At Louisville the wind averaged 46 miles an hour from the southwest, between 10 a. m. and 1 p. m., with a maximum velocity of 60 miles, and at Cincinnati it averaged 31 miles per hour, with a maximum velocity of 52 miles. Sugar Creek is on a line between Louisville and Cincinnati and directly northeast of Louisville. With the river free of ice below large waves pounded against the foot of the gorge. The high wind, with a temperature of about 60°, blew against the surface of the gorge and melted the ice rapidly on the surface and in the crevices along the surface, and probably moved or swayed slightly many of the large hills of ice extending from 20 to 30 feet above the surface, causing cracks and crevices through the gorged ice. At about 11:30 a. m., the same day the ice showed signs of breaking at the head of the gorge. It started and stopped several times during the next hour at 2 miles below North Landing and at Rising Sun. Between 12:30 and 1 p. m. it began to move from Sugar Creek to Rising Sun. The gorge ice passing Dam No. 39 during the early afternoon consisted principally of huge cakes of ice, some of which, striking the top of the cofferdam 25 feet under the surface of the water, would rise to a height of 25 to 30 feet above the surface when rolling over the cofferdam. This ice was clean and comparatively free of débris. Later the ice became more broken, and the first broken barges and boats which had been held in the gorge at North Landing began to pass Dam No. 39 at about 4 p. m. Between this time and dark 68 pieces of boats and barges of all descriptions were counted passing in the ice. Although the principal break in the gorge occurred at 1 p. m. it took more than seven hours for the gorge to completely break.

As soon as the gorge broke the river began falling rapidly, and, with the increasing current, all of the gorged ice above started moving. At Aurora the ice started moving at 2 p. m. and the river fell 5 feet in the next two hours. At Fernbank, 13 miles below Cincinnati, the ice started moving at 2:15 p. m. and the river fell 4 feet in the next 2 hours and 45 minutes. At Cincinnati the river reached a crest of 61.8


ELEVATIONS ABOVE SEA-LEVEL
2500 FEET
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200 FEET
1100
1000
900
800
700
540
535
530
525
520
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510
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480
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470
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460
455
450
445
440
435
430
425
420
415
410
405
400
395
390
INDIANA
NO. 1
NO. 2
NO. 3
NO. 4
NO. 5
ROAD
1884 H. W. - 478.0
1884 H. W. - 481.5
1884 H. W. - 483.0
1884 H. W. - 480.0
L. W. - 417.7
CROSS SECTION NO. 3
AT HEAD OF BIG BONE ISLAND
516 M. + 395 FT. ±
CROSS SECTION NO. 5
BELOW NORTH LANDING
510 M. + 150 FT. ±
CROSS SECTION NO. 1
4000 FT. ± ABOVE MOUTH BIG SUGAR CREEK
522 M. + 880 FT. ±

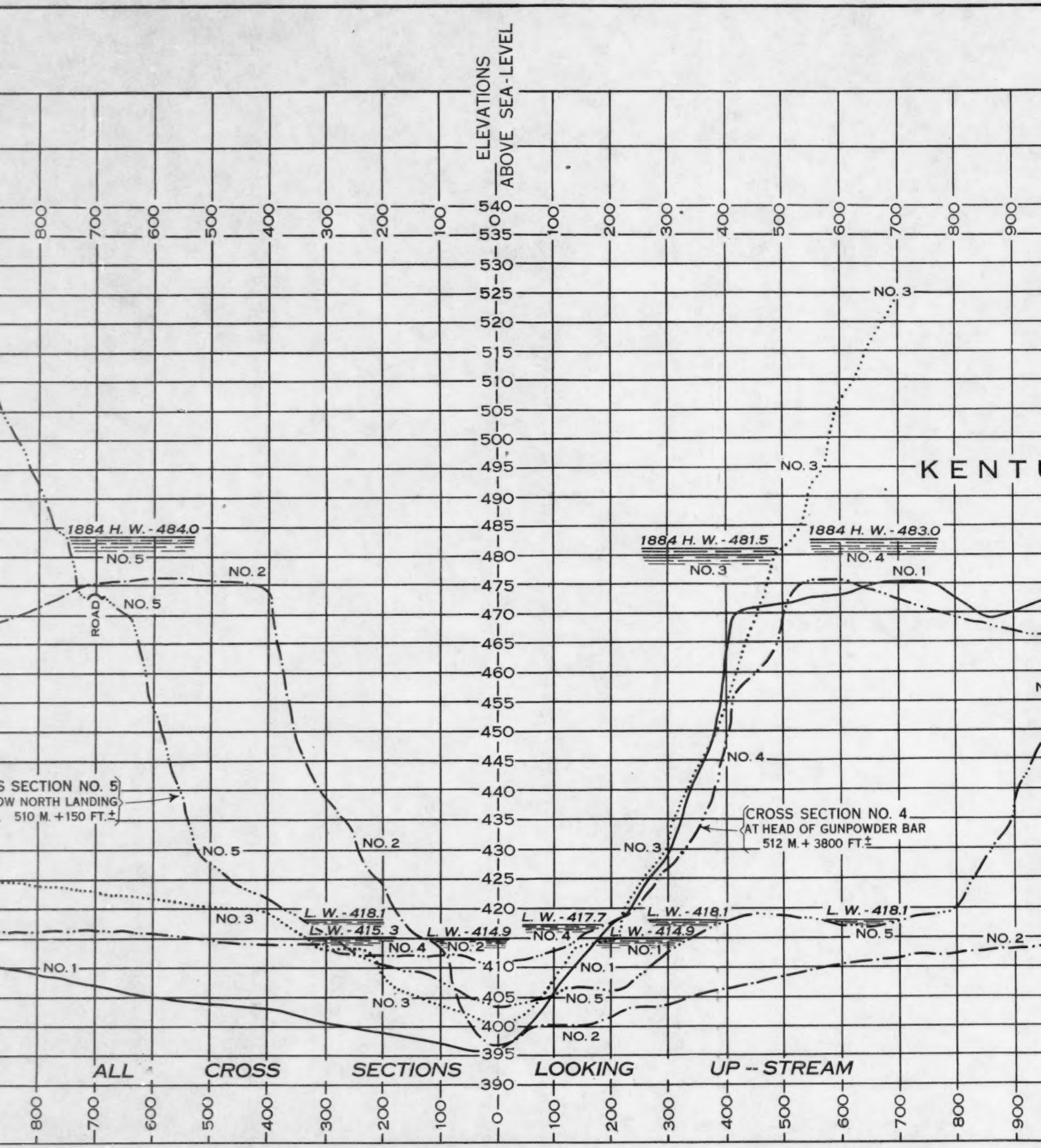
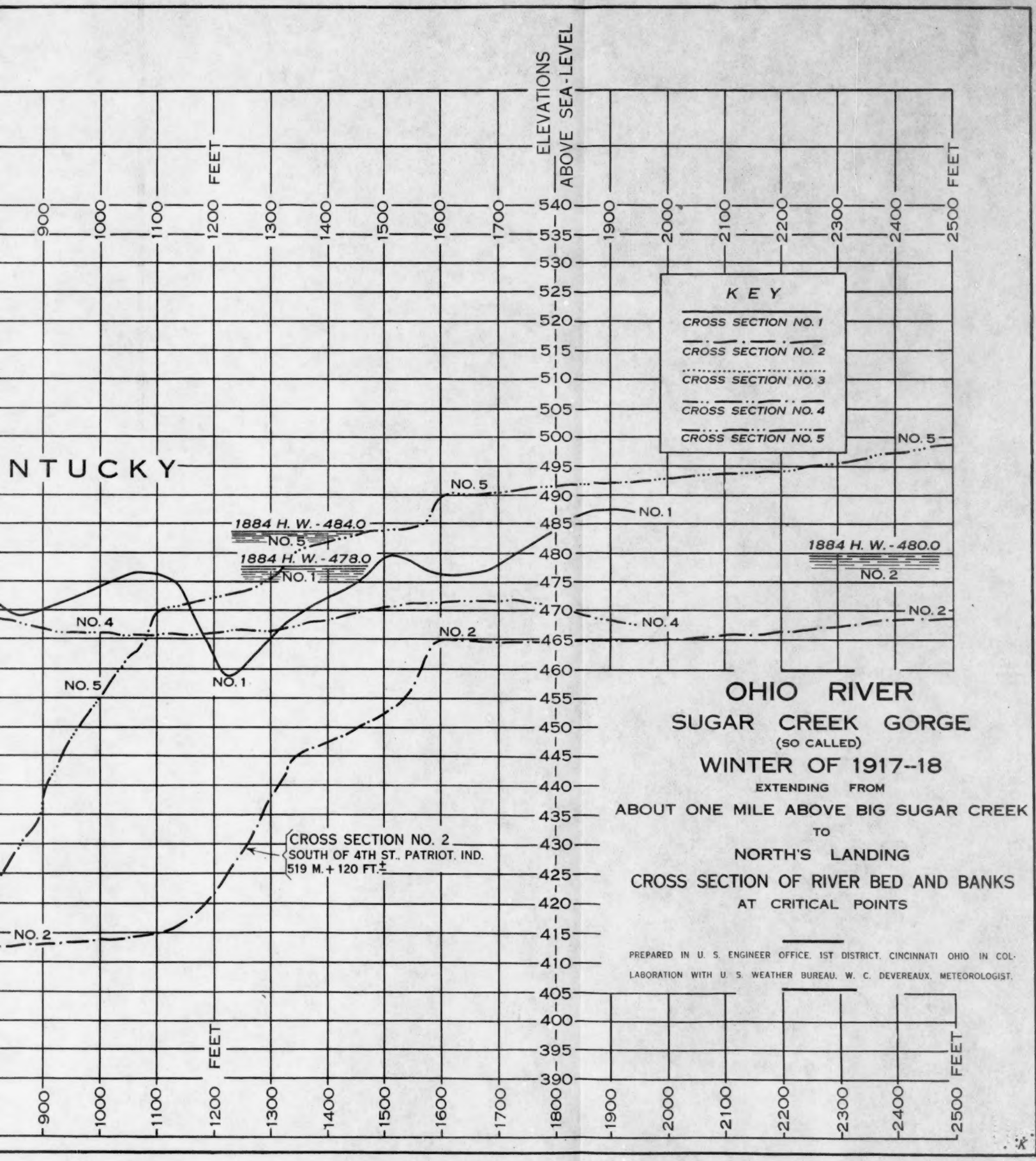



Fig. 2.—Cross sections Ohio River in Sugar Creek gorge. (Positions of cross sections are indicated on figure 1. Compare also figure 1a.)




# OHIO RIVER

## SUGAR CREEK GORGE

(SO CALLED)

## WINTER OF 1917--18

EXTENDING FROM

ABOUT ONE MILE ABOVE BIG SUGAR CREEK

TO

NORTH'S LANDING

CROSS SECTION OF RIVER BED AND BANKS

AT CRITICAL POINTS

PREPARED IN U. S. ENGINEER OFFICE, 1ST DISTRICT, CINCINNATI OHIO IN COL-LABORATION WITH U. S. WEATHER BUREAU, W. C. DEVEREAUX, METEOROLOGIST.

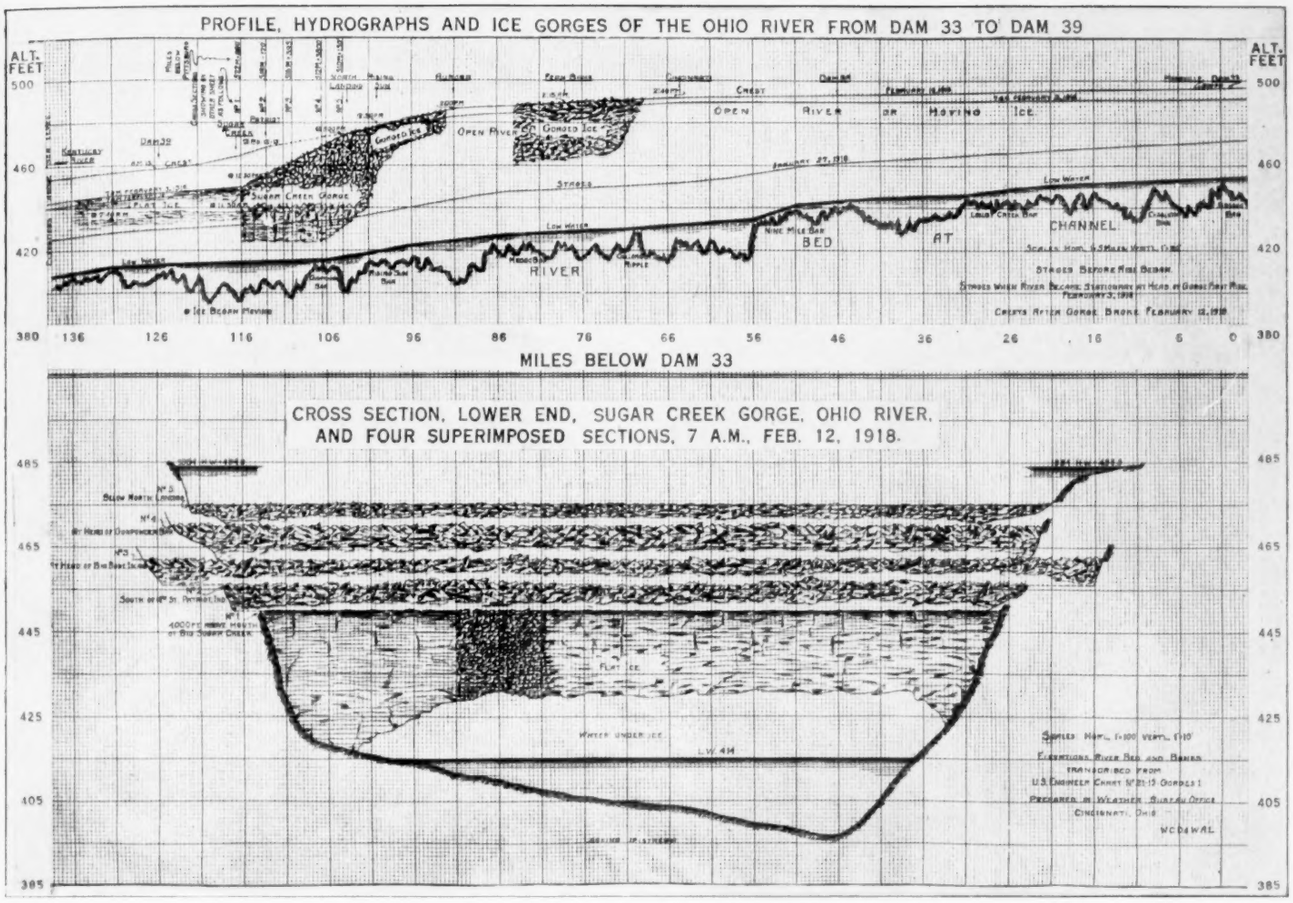



Fig. 3.—Profile and hydrographs, Ohio River and superposed cross sections of Sugar Creek gorge.

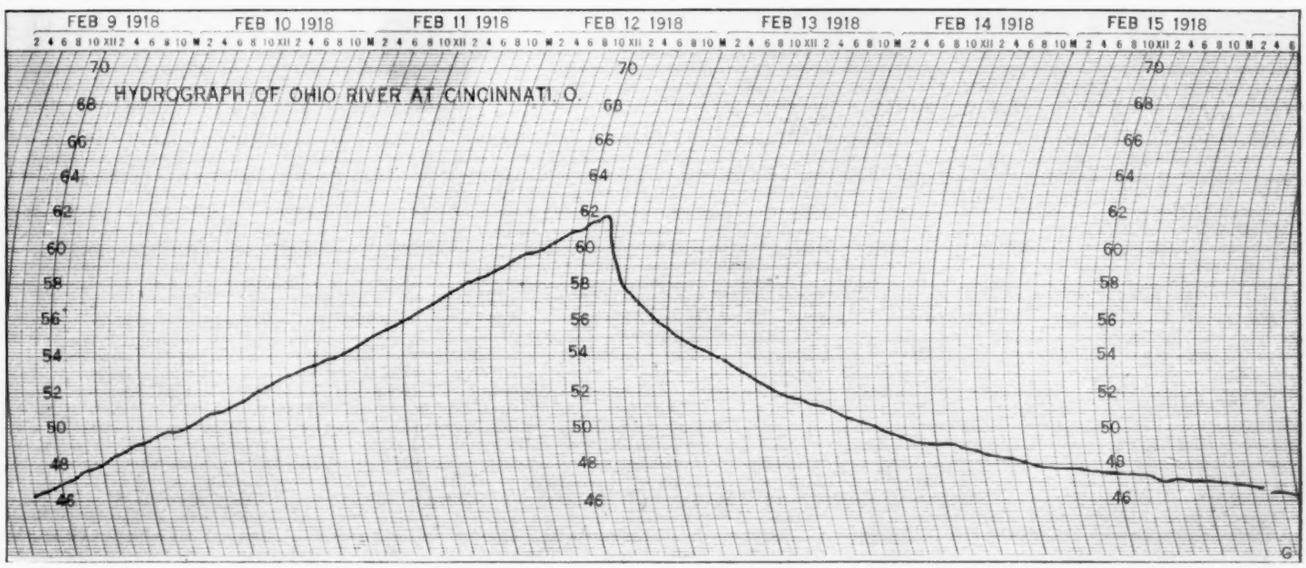



Fig. 4.—Hydrograph, Ohio River at Cincinnati, Ohio, Feb. 9-15, 1918.

Fig. 5.—Gorged ice below Southern Railway bridge at Cincinnati, Ohio.

feet at 2:40 p. m. In the next 5 minutes it fell 0.2 feet, but in the 15 minutes between 2:45 p. m. and 3 p. m. it fell 1.1 feet. After 3 p. m. the rate of fall gradually decreased but continued rapid for the following two days. At Dam No. 33, 104 miles above the gorge, the river became stationary at 8 p. m. and continued so for 24 hours, although the river at Portsmouth above had been rising 0.2 foot per hour, or more, for several days. By the morning of the 14th the river was below flood stage at all places in the Cincinnati district.

Below the gorge the river rose rapidly (about 2 feet per hour) for the first 5 hours after the break and then rose more slowly. At Patriot, within the gorge and 3 miles from the lower end, the crest was between 55 and 56 feet about midnight of February 12–13, and at Dam No. 39, 10 miles below the gorge, the crest was 44.8 feet the following morning.

*Warnings.*—Warnings of the floods and the breaking of the ice gorges were issued whenever possible, and the river interests were kept fully advised of the conditions at all times. It was not possible to issue warnings for the floods at Pikeville, Williamson, and Logan, as in each case these places are the ones farthest up the tributaries from which river or rainfall reports were received.

At 9 a. m. January 28, 1918, warnings were issued that the ice gorges would break in the Ohio from the mouth of the Kanawha to below Ashland that afternoon and night, and from below Ashland to the mouth of the Kentucky within 36 to 48 hours. The ice gorges broke at all places as forecast, except at the Sugar Creek gorge.

During January 29 the warnings were repeated for the river from Portsmouth down, and special bulletins were issued every hour giving progress of the breaking of the gorges.

Warnings were not issued for flood stages in the Ohio above Cincinnati and none occurred. The morning forecast of January 30 contained a warning that flood stage might be exceeded at Cincinnati if the gorges below held. The river passed the flood stage at 8:30 a. m. January 31 and all interests were advised to keep a few feet above the rising water, as the river would continue to rise if the gorge below held. From January 30 to February 2, when the river was falling, bulletins were issued about every hour and three telephones were in almost constant use giving out the information.

At 6 p. m. February 9 warnings were issued that if the gorge in the Licking broke the river at Cincinnati would rise 5 to 10 feet. The warning was telephoned to all the river interests. The gorge did not break but the river rose quite rapidly and passed the flood stage again the next morning.

On February 10, 11, and 12, warnings and special bulletins were issued at frequent intervals. Briefly the forecasts were as follows:

*February 10, 9 a. m.*—"If ice gorge below Butler in Licking breaks river at Cincinnati will rise sharply several feet."

*February 11, 9 a. m.*—"The danger of a further big rise from the Licking is apparently passed. The river from Cincinnati to Rising Sun will continue rising about 0.2 foot per hour for the next two days or longer if the gorge above Sugar Creek holds, and the stage at Cincinnati will go above the 60-foot stage. If the gorge goes out, the river will begin to fall."

*February 11, 11 a. m.*—"(For region below gorge.) Gorge above Sugar Creek may break or disintegrate within next day or two and there will be a decided rise in river below of about 20 feet."

*February 12, 9 a. m.*—"If gorge above Sugar Creek holds the river at Cincinnati will rise about 0.2 foot per hour this afternoon and to-night, reaching a stage between 64 and 65 feet Wednesday morning, after which time, if gorge still holds, the river will probably not change much."

A telephone message relayed through four exchanges was received at 2 p. m., February 12, stating that the gorge had broken. After this had been verified by the traffic chief of the telephone company and a similar report obtained from the wire chief of the Western Union Telegraph Co., at Louisville, Ky., the information was distributed by special bulletins and telephone.

*Losses from floods and ice gorges.*—Losses sustained by river craft as a result of the breaking of the ice gorges between January 29 and February 12, 1918, from the mouth of the Kanawha to the mouth of the Kentucky, are estimated at $833,000. This includes the loss of the Baltimore & Ohio bridge (about $200,000) across the Great Miami near the mouth. The Marine Underwriters estimate that the loss to river interests were between $600,000 and $650,000, exclusive of the Baltimore & Ohio bridge.

The losses due to floods in the Guyandotte and Big Sandy Valleys, and the two floods in the Ohio from Cincinnati to Rising Sun, Ind., are estimated as follows:

| | |
|---|---|
| (1) Loss of buildings, factories, bridges, etc | $350,000 |
| (2) Loss of farm property | 5,000 |
| (3) Loss of farm property due to suspension of business | 800,000 |

**Value of property saved by warnings, $8,000,000.**

TABLE 1.—*Hourly stages of the Ohio River at Cincinnati from 6 a. m. to 7 p. m. from Jan. 30, 1918, to Feb. 6, 1918, and from Feb. 9, 1918, to Feb. 14, 1918.*

[Feet above gage zero whose altitude is 429.8 feet M. S. L.]

| Date. | A. M. | | | | | | Noon. | P. M. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | 7 | 8 | 9 | 10 | 11 | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1918. | | | | | | | | | | | | | | |
| Jan. 30 | 22.7 | 23.2 | 25.0 | 26.8 | 27.8 | 35.2 | 38.3 | 41.0 | 43.0 | 45.0 | 46.2 | 45.2 | 44.8 | 44.7 |
| 31 | 48.5 | 49.4 | 49.6 | 51.1 | 52.2 | 54.8 | 55.7 | 56.3 | 56.9 | 57.1 | 57.5 | 58.0 | 58.3 | 58.6 |
| Feb. 1 | 60.7 | 60.8 | 60.9 | 61.0 | 61.0 | 61.0 | 61.0 | 61.1 | 61.1 | 61.1 | 61.2 | 61.2 | 61.2 | 61.2 |
| 2 | 61.0 | 61.0 | 61.0 | 60.9 | 60.8 | 60.7 | 60.6 | 60.6 | 60.5 | 60.4 | 60.4 | 60.3 | 60.2 | 60.1 |
| 3 | 59.2 | 59.1 | 59.0 | 58.9 | 58.8 | 58.7 | 58.6 | 58.5 | 58.4 | 58.3 | 58.1 | 57.9 | 57.7 | 57.6 |
| 4 | 56.6 | 56.5 | 56.4 | 56.3 | 56.2 | 56.1 | 56.0 | 55.9 | 55.8 | 55.7 | 55.6 | 55.5 | 55.4 | 55.3 |
| 5 | 54.1 | 54.0 | 53.9 | 53.8 | 53.6 | 53.5 | 53.4 | 53.2 | 53.1 | 53.0 | 52.9 | 52.8 | 52.7 | 52.6 |
| 6 | 50.8 | 50.7 | 50.7 | 50.6 | 50.5 | 50.4 | 50.4 | 50.3 | 50.2 | 50.0 | 49.9 | 49.8 | 49.7 | 49.6 |
| 9 | 46.1 | 46.2 | 46.3 | 46.5 | 46.7 | 46.8 | 47.0 | 47.0 | 47.2 | 47.5 | 47.6 | 47.8 | 48.0 | 48.3 |
| 10 | 50.1 | 50.3 | 50.6 | 50.8 | 50.9 | 51.0 | 51.2 | 51.4 | 51.6 | 51.8 | 52.0 | 52.2 | 52.4 | 52.6 |
| 11 | 54.7 | 54.9 | 55.1 | 55.3 | 55.5 | 55.8 | 56.0 | 56.2 | 56.4 | 56.8 | 57.0 | 57.3 | 57.6 | 57.8 |
| 12 | 60.1 | 60.3 | 60.5 | 60.7 | 60.9 | 61.0 | 61.3 | 61.5 | 61.6 | 60.5 | 58.8 | 58.1 | 57.4 | 57.1 |
| 13 | 54.0 | 53.8 | 53.5 | 53.2 | 53.0 | 52.8 | 52.6 | 52.4 | 52.2 | 51.9 | 51.8 | 51.6 | 51.5 | 51.3 |
| 14 | 49.6 | 49.4 | 49.3 | 49.2 | 49.1 | 49.0 | 48.8 | 48.9 | 48.8 | 48.7 | 48.5 | 48.4 | 48.3 | 48.2 |

The crest stage in the first rise was 61.2 feet from 4 p. m. to midnight of February 1.

The crest stage in the second rise was 61.8 feet at 2:40 p.m. February 12.

River stages at Cincinnati at frequent intervals on February 12 after the breaking of the gorges below:

| | Feet. | | Feet. | | Feet. |
|---|---|---|---|---|---|
| 2:30 p. m. | 61.7 | 3:28 p. m. | 59.6 | 4:27 p. m. | 58.6 |
| 2:40 p. m. | 61.8 | 3:32 p. m. | 59.5 | 4:30 p. m. | 58.4 |
| 2:45 p. m. | 61.6 | 3:35 p. m. | 59.4 | 4:40 p. m. | 58.3 |
| 3:00 p. m. | 60.5 | 3:40 p. m. | 59.3 | 4:45 p. m. | 58.2 |
| 3:07 p. m. | 60.4 | 3:43 p. m. | 59.2 | 5:00 p. m. | 58.1 |
| 3:15 p. m. | 60.2 | 3:45 p. m. | 59.1 | 5:07 p. m. | 58.0 |
| 3:18 p. m. | 60.0 | 3:48 p. m. | 59.0 | 5:25 p. m. | 57.8 |
| 3:20 p. m. | 59.9 | 4:00 p. m. | 58.8 | 5:32 p. m. | 57.6 |
| 3:25 p. m. | 59.7 | 4:15 p. m. | 58.7 | | |

—*W. C. Devereaux, Meteorologist in Charge.*

## *Louisville, Ky., river district.*

Owing to the remarkable cold weather which prevailed during practically the whole of December, 1917, and January, 1918, the average temperature of both months being considerably lower than for any of the corresponding months since the establishment of the national weather service in 1871, ice of unusual thickness formed on all the streams and rivers in the district. The Kentucky River was frozen, with ice more than 1 foot thick, from its source to its mouth. Also, the Ohio became covered with ice equally thick from the mouth of the Kentucky River to Cloverport, Ky., except over the falls of the Ohio at Louisville and for a mile or two above the Government dam at the same place; and even in this latter stretch there was heavy ice near the shore. The harbor and the canal at Louisville were kept open by breaking the ice with boats. The ice in these rivers and streams, except as mentioned, remained intact up to near the end of January, there being no thawing weather of sufficient length or any heavy rains to loosen and break it up.

*Kentucky River.*—About January 26 heavy rains set in over the headwater tributaries of the Kentucky River and continued during the greater portion of three days. This rain fell over sections already covered with deep snow, and as the temperature was above freezing, the combined rain and snow water resulted in great floods and much damage in the upper reaches of the Kentucky. In the upper Kentucky River stages approaching the highest on record were reached. The town of Beattyville was inundated for several hours, a flood crest of about 45 feet being reached January 29. The high waters broke up the ice, which was carried down stream forming gorges and causing large loss to log booms and river craft. The damage along the upper and middle Kentucky above Frankfort is estimated to have been about $200,000. There was little or no damage at Frankfort, although a menacing gorge formed just below that city during the night of the 28–29th. However, the gorge broke and passed out during the afternoon of the 29th. A crest slightly above flood stage was reached at Frankfort. Below Frankfort the only damage of consequence was done at the mouth of the Kentucky River on January 30, when the ice masses from that river passed out into the Ohio. Here a number of boats, including sev-

eral of the large Ohio River boats, had sought harbor in anticipation of damage from the ice in the Ohio. These boats were carried out into the Ohio by the heavy ice, and most of them crushed, sunk, or damaged. The loss here is estimated to have been about $100,000. Also one man was drowned. The ice floes from the Kentucky, containing boats and wreckage, lodged in the Ohio about 2 miles below the mouth of the Kentucky, but continued on down the Ohio with the breaking of the ice at Madison on February 1. The most valuable boat in this floe, and one of the largest excursion boats plying the Ohio, the "Island Queen," was finally brought to shore and saved at Louisville.

*Ohio River.*—The most important ice gorge and the one producing by far the most menacing situation in the Ohio and for the Louisville district, was the one that formed in the Big Sugar Creek bend, about 81 miles above Louisville. (See pp. 87–89.)

The Sugar Creek gorge was something over 15 miles in length, and produced a difference in water level above and below of 30 feet. This gorge held more or less firmly until February 12, being gradually added to until its length became nearly 30 miles. In the meantime practically all the ice in the entire Louisville district, which is below the gorge, broke up and passed out.

February 1, about noon, the whole field of ice in front of and immediately below Madison moved in one great sheet, carrying with it a number of barges and several river craft tied up there, the damage being about $20,000. February 1, about 9:50 a. m., shore ice at the foot of Sixth Street, Louisville, broke and passed out over the dam, carrying away and destroying the houseboat of the Louisville Power Boat Club and nine motor boats, one worth about $7,000, the loss here being about $20,000. About 3 p. m. great ice sheets immediately above Louisville, near the Louisville Water Works pumping station, moved out in one great mass, carrying with it a number of coal barges and many small boats, causing a loss of about $25,000.

February 2, heavy ice floes containing many river craft and wreckage of all kinds passed by Louisville the greater part of the day. The heavy ice swept away portions of the Government boule dam at Louisville, the extent and cost of damage to which can not be even approximated until a low stage of water permits a careful examination. By February 4 the ice had about all passed out of the Louisville district. Much of the floating equipment used in the construction of the dam below West Point was carried away by the ice, but as considerable of this is expected to be rescued lower down the river, no estimate can be given as to the damage here, which is about the only damage of any consequence in the Louisville district below Louisville.

February 12, the Big Sugar Creek bend ice gorge began breaking up about 1 p. m., when about 6 miles of the lower end broke loose and moved out. This was soon followed by the breaking up and moving out of the whole gorge. The first heavy ice from the gorge reached Madison about 2:15 p. m. and Louisville about midnight. The river was filled from bank to bank with heavy floating ice, containing all kinds of river craft and wreckage, during all of the 13th. Very little, if any, of this wreckage, however, came from the section of river and tributaries under the Louisville district. On account of the open water that prevailed in this district during the 10 days preceding the breaking up of the gorge, all craft, wharf boats, etc., remaining that could be moved were taken to safe harbor. Craft to the value of more than $1,000,000 was harbored in the Portland Canal, at Louisville, and all saved.

The river, of course, rose rapidly after the breaking of the big gorge, but it did not reach the flood stage at either Madison or Louisville. A crest of 44.7 feet was reached at Madison about 3 p. m., February 13, and 26.7 (upper gage), 51.9 feet, lower gage, at Louisville at 6 a. m., February 14.

The ice floes reached Cloverport, 104 miles below Louisville, during the night of the 13th–14th. A flood crest of 42 feet (2 feet above flood stage) was reached at Cloverport in the early morning of February 15.

All river interests were kept fully advised and warned during the entire time of the critical situation produced by the ice, gorges, and damming of water.—*F. J. Walz, Professor of Meteorology in Charge.*

## *Evansville, Ind., river district.*

Floating ice made its appearance in practically all of the district during the first decade of December, 1917. River navigation ceased in all of the district, and the river froze over at most places between December 10 and 15; while the ice in the lower part of the district, from Mount Vernon, Ind., down, remained solid from this time until the general break-up occurred in February, 1918, it broke and moved slightly at most points above Mount Vernon on December 18; another movement also set in at all points in the upper and middle parts of the district during the night of December 22 and 23; the river was nearly clear of ice down to and including Henderson, Ky., from December 23 to 28, inclusive, but floating ice again appeared in all of that part of the district on December 29, and by January 3 or 4 the river, above Mount Vernon, was again filled with broken ice having but little, if any, movement; this condition continued until the night of January 11 and 12, when the river was frozen entirely across at all points in the district for the first time since February, 1905. Many people crossed the river on the ice at all points in the district from January 15 to 21, inclusive; during this interval some hauling with teams was also reported to have been done across the river on the ice at, or near, Mount Vernon, Ind. The ice held firmly in all of the district until February 1, when the first signs indicating a general break-up made their appearance between the mouth of the Green River and Evansville, Ind.; the appearance of these signs in that part of the district was probably due to the running out of the Green River ice, which broke in the upper pools of that stream on January 25 and reached its mouth on February 1.

The general break-up and running out of the Ohio River ice in this district, began above Newburg, Ind., on February 2 from Newburg, Ind., down to include Henderson, Ky., on February 3, and from a point slightly above West Franklin, Ind., down, on February 4. Heavy ice running quite freely above Henderson until about 5 a. m. of February 4, when it began to gorge in the Evansville bend; river rose rapidly at points immediately above the jamming ice; at Evansville the river rose from a stage of a little less than 30 feet to a stage of 35.5 feet during the two hours ending at 7 a. m. of February 4. While the gorge continued to form in the Evansville bend, the ice containing considerable wreckage kept passing the Evansville wharf until 4 p. m. of February 4 when all movement ceased. By 7 p. m. of that date the gorge extended from about Howell, Ind. (just below the Evansville bend), up to above the mouth of the Green River, and by daylight of February 5 up to above Newburg, Ind., making the total length of the gorge (locally known as the Evansville gorge) about 15 miles. The ice in this gorge was the heaviest ever observed along this stretch of the river; it was solid and quite clear, and in front of Evansville the cakes in the gorge varied between 14 and 22 inches in thickness. (See fig. 7.)

The ice in the lower part of the district, from West Franklin down, which broke and began moving shortly before noon of February 4, continued running until about 9 p. m. of that date when it formed the second gorge in the district; this second gorge extended from about 4 miles above West Franklin, Ind., down far beyond the lower end of the Evansville River district, was in fact the upper end of an immense ice jam of nearly 100 miles in length, which was reported to have extended down the Ohio River to Birdsville, Ky.

The upper end of the district down to below Rockport, Ind., and a short stretch of river from Howell, Ind., down to Henderson, Ky., were practically free of ice from February 4 to 14.

The ice in the lower gorge began moving at West Franklin and Mount Vernon shortly after the noon hour on February 6, and at Uniontown, Ky., about noon of February 7; the river was free of ice from Henderson, Ky., and below after 3 p. m. of February 7, the only ice remaining in the district being the Evansville gorge.

The Evansville gorge held firmly until the night of February 10 and 11 when some movement occurred on the Kentucky side at its upper end near Newburg, Ind.; slight movements also occurred during the afternoon of February 11 in front of Evansville; during the early morning of February 12 slight movements occurred in various parts of the gorge, and by 4 p. m. of that date a general, continuous, but slow, movement had begun; by 6 p. m. the entire gorge appeared to be moving freely, and considerable floating property, abandoned in the ice, passed Evansville before dark; by daybreak of February 13, the main channel at Evansville was practically clear, with a fringe about 100 yards, wide of heavy ice remaining stranded on the Indiana bank; by morning of February 14 the ice from the Evansville gorge had moved down beyond the mouth of the Wabash, and while the Ohio River was not entirely free of floating ice, it had an open channel throughout the entire district. This condition was, however, of brief duration, as the heavy ice from the upriver gorges made its appearance in the upper end of the district on February 14; the upriver ice which was very heavy, and carried with it an immense amount of wreckage, passed through the district on February 14 and 15, filling the river from bank to bank. In passing through the district the upriver ice carried with it nearly all the ice that had been left stranded along this stretch of the river when the Evansville gorge went out. Except for some light floating ice in places, the Ohio was free of ice in all of the district by February 16.

The ice, in moving out, and through the district, did an immense amount of damage to all kinds of floating property, banks, inclines, etc. While there were, no doubt, a great many minor losses in various parts of the district that were unheard from, the principal losses will aggregate $127,905, which were distributed as follows:

| | |
|---|---|
| At Tell City, Ind | $300 |
| At Owensboro, Ky | 14,650 |
| At Evansville, Ind | 31,650 |
| At Dam No. 48 (5 miles below Henderson, Ky.) | 59,055 |
| At Mount Vernon, Ind | 21,000 |
| At Uniontown, Ky | 1,250 |
| Total | 127,905 |

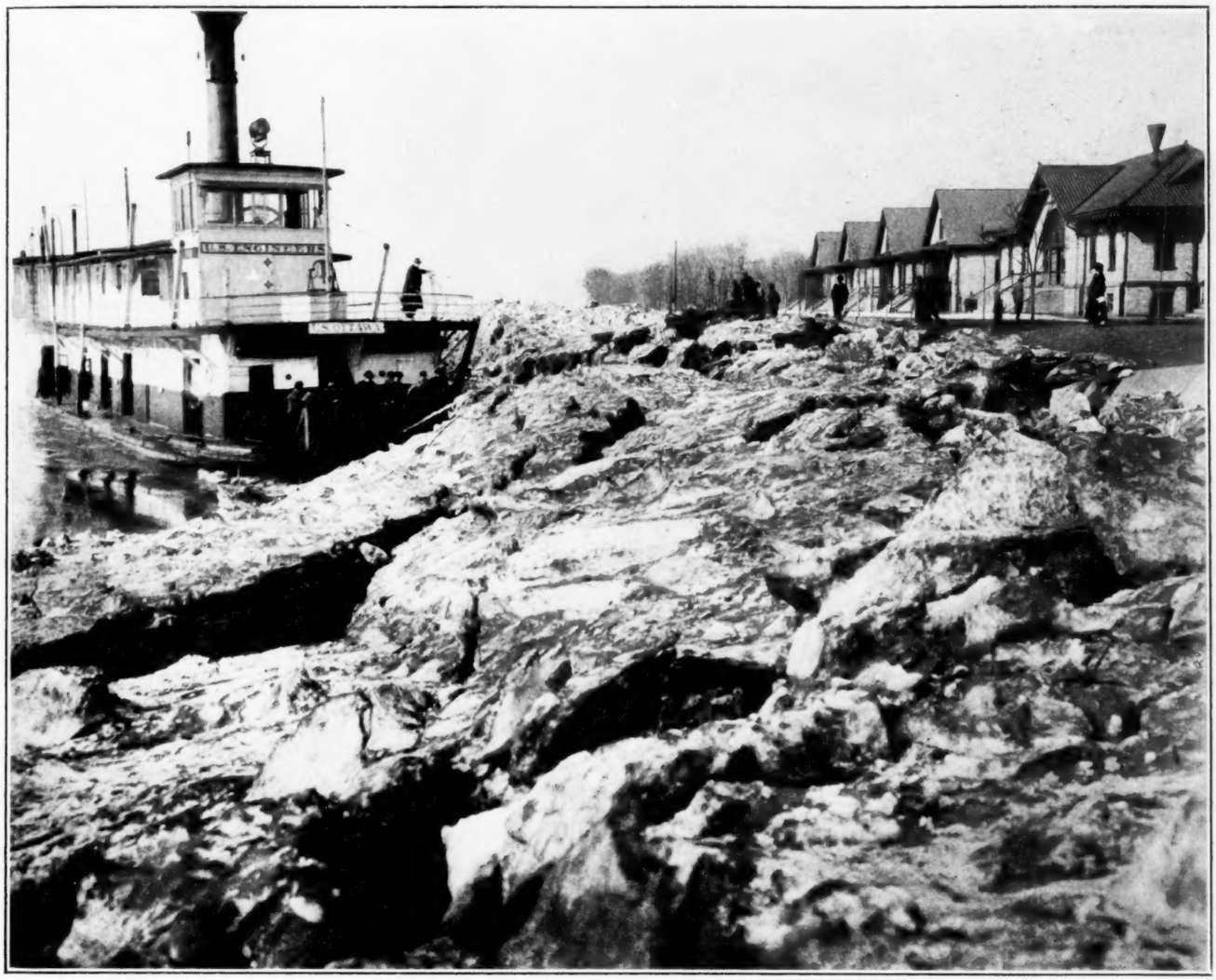


Fig. 6.—Ice left on banks at Fernbank, Ohio, as gorge broke.

Fig. 7.—Gorged ice in front of Evansville, Ind., Feb. 5, 1918.

Fig. 8.—Gorge in Mississippi 4 miles south of Osceola, Ark. (Ice resting on bar at this point.)

While some of the lost or damaged property will, very likely, be salvaged and repaired, the permanent losses in the district will, it is believed, be fairly represented by the foregoing total as the minor losses which were not reported will fully equal in value the property salvaged.—*Albert Brand, Meteorologist in Charge.*

### *Cairo, Ill., river district.*

As applying to the months of December, 1917, and January, 1918, the winter of 1917–18 broke all records for heavy snow and low temperature. That is certainly true at Cairo and is probably true as applied to the lower Ohio and Tennessee Rivers.

At Cairo, Ill., December 9, 1917, a minimum temperature of —7° F. was recorded, the earliest date in that month when such severe temperature has occurred within the history of the station extending back 46 years; January 12, 1918, a minimum temperature of —16° occurred, equal to the lowest ever recorded here in any month; the mean temperature for December, 1917, 28.7°, was the lowest mean for that month ever recorded with the exception of 26.4°, in December, 1876; and the mean temperature for January, 1918, 21.0°, was about 4 degrees lower than that of any previous month, of record. Taking the two months, January, 1918, and the month preceding, combining their mean temperatures and dividing by 2, giving 24.8° as a basis of comparison, we had a mean daily average 4.6 degrees lower than that of any previous two consecutive months in the history of the station.

During the 62 days comprising December, 1917, and January, 1918, 35 days, had a maximum temperature below 32°.

As a consequence of the extremely cold weather ice formed in the lower Ohio and Tennessee Rivers in quantities never before recorded, and which the oldest inhabitants held neither in memory or tradition. January 12, 1918, people crossed the Ohio River at Cairo on the ice for the first time known, shore ice being about 18 inches in thickness, that in the channel probably about 2 inches.

The Mississippi in the vicinity of Cairo has previously been frozen solidly enough to drive cattle across, and no unusual records, relative to ice in that stream, were made, except that portion below Cairo where ice from the Ohio affected it.

The Ohio, below the mouth of the Wabash, closed about December 11, 1917, remained so for about 10 days, open until January 1, 1918, closed until February 3, when slight movements occurred, the final break-up occurring during the night of February 6–7; the maximum thickness of ice in the vicinity of Shawneetown, Ill., was 18 inches, and when the ice went out considerable gorging occurred, the river going above flood stage on the 8th, ice covering the fields on both sides of the river in that vicinity to a distance of one-half mile, breaking down fencing and barns; the fencing and buildings on this class of land are usually of flimsy structure and no considerable amount of damage resulted; however, a steamboat and three or four gasoline boats were destroyed, having a total valuation of $15,000.

In the Tennessee River, at Florence, Ala., gorges described as 70 feet high formed at the canal and a number of families removed from their houses as a precautionary measure, although no damage eventually occurred; the main channel of the stream did not close at any time, but seemed to almost close at intervals from January 12–16, 1918. Maximum thickness of shore ice was about 18 inches.

At Riverton, Ala., also, the main channel remained open, some small craft being damaged by floating ice, having a valuation of $1,000.

At Savannah, Tenn., a gorge formed about 8 feet in height and another gorge, upstream, was reported to have been 14 feet in height; the damage in that vicinity amounted to about $2,200 in all, lumber and buoys used in the operation of the local ferry boat being carried away by ice and flood.

Ice appeared at Johnsonville, Tenn., December 16, channel remained open until January 13 and 14, at which time it appeared possible to cross on foot, although the passage was not attempted by anyone; channel cleared January 15, with some slight damage to small boats, none being lost; the river became free from ice January 28–29.

The mouth of the Tennessee River, near Paducah, Ky., being reputed free from ice hazards, has been used as a winter anchorage for many steamboats, especially upper Mississippi River craft, for a number of years. The unprecedented ice conditions prevalent in the Tennessee and lower Ohio Rivers during the past winter made the situation there hazardous, and during the early morning of January 29, 1918, gorges carried away or sunk 8 steamboats, valued collectively at $350,000. The steamers *John L. Loury* and *Joe Fowler* were not carried away with the ice, but were damaged to the extent of about $2,500; also, the ferryboat *City of Cairo*, in winter harbor at the mouth of the Tennessee, was damaged about $1,000.

At Metropolis, Ill., Joppa, Ill., and Mound City, Ill., considerable damage was done with the passing of the gorge January 29, but the full extent of damage has not been estimated.

At Cairo, two wharf boats were sunk, one wharf boat damaged by being pushed ashore by the ice, and all boats in the harbor were injured. The *Sprague*, the largest towboat plying in inland waters, was carried away but has since been recovered; the two wharf boats sunk had been in use a great many years, and were not of high intrinsic value, except as a matter of utility; the entire local damage to river craft probably amounted to $50,000.

At Hickman, Ky., on the Mississippi below Cairo, a steamboat belonging to the Mengel Box Co., was reported lost, value not estimated; and slight damages resulted from the passage of the gorge carrying away small craft and two houseboats at New Madrid, Mo.

A gorge at Columbus, Ky., held from late in December (Dec. 29, 1917) until January 30, 1918, breaking when the Ohio-Tennessee River gorges were forced upon it; foot passage between Kentucky and Missouri, across the frozen Mississippi, occurred at that point between January 10 and 15.

Taken altogether, ice conditions during the past winter throughout this river district were without precedent.—*R. T. Lindley, Meteorologist in Charge.*

## THE MISSISSIPPI RIVER.

### *St. Paul, Minn., river district.*

The channel closed at Robert Street bridge (location of gage) during the night of December 3-4, 1917; the thickness of the ice on Monday, December 10, was 7 inches; it increased to a maximum thickness of 20 inches on February 11. During the afternoon and night of Sunday, March 3–4 the ice ran out, and on the morning of March 4 the channel was open from the High Dam (about 3 miles above the mouth of the Minnesota River) to South St. Paul (about 5 miles below the gage). During the entire winter there was a narrow strip of open water along the shore on the gage side, from a large trunk sewer, about a half mile above the gage, to a mile below the gage.

The breaking up of the ice was gradual and without any rise of the water and therefore without any damage resulting.

At this date—March 20—the river is open from St. Anthony Falls, at Minneapolis, to near Hastings, and possibly farther down (20 miles).

It is expected that the ice in Lake Pepin will open in a few days.—*J. N. Ryker, Meteorologist in Charge.*

### *Dubuque, Iowa, river district.*

The Mississippi River is now (Mar. 16, 1918) open at and near Dubuque. No gorges have formed, and the break-up has been wholly without damage. In spite of the severity of the past winter the thickest ice in this section was about 2 feet, which is not unusual. The heavy snow covering prevented extra heavy ice such as occasionually forms during a cold but "open" winter.

On the average the Mississippi River opens up here on March 15, and this year the opening was two days earlier than the average. Some of the rivers of this district, and also a portion of the Mississippi above Dubuque, are still frozen, but I think the break-up will be soon and without unusual incident throughout the river district.—*J. H. Spencer, Meteorologist in Charge.*

### *Davenport, Iowa, river district.*

No gorges worthy of mention formed in the Davenport district during the winter of 1917–18. Notwithstanding its great thickness at the beginning of February, the ice broke up about two weeks earlier than usual and passed out quietly, without doing any particular damage. The river opened at Muscatine on March 1, at Davenport and Clinton on March 2, and at Le Claire on March 3.—*J. M. Sherier, Meteorologist in Charge.*

### *Keokuk, Iowa, river district.*

The Mississippi River was open for 2 miles south of the Keokuk Dam during the entire winter owing to the discharge from the power house.

At Warsaw, Ill., 5 miles south, it was frozen, and teams were crossing on the ice until the middle of January.

By February 14 the ice had moved out from the lower Des Moines and from the Mississippi at Warsaw, gorging between Gregory and Canton, Mo. This gorge caused a rise of 3 feet at Warsaw, and the rise extended to Keokuk.

At Ottumwa, Iowa, on the Des Moines River, the ice broke up on February 12, a gorge formed north of Ottumwa causing a fall of 3 feet by the 19th, the river closing temporarily by the 19th and opening permanently on the 22d.

North of Keokuk the ice formed during the winter to the thickness of 24 inches, breaking up for a short distance above the dam by February 18, and by February 25 the ice was broken up far above the dam.—*Fred J. Gosewisch, Observer in Charge.*

### *Hannibal, Mo., river district.*

The ice in the Mississippi River in this vicinity formed early, attained unusual thickness and broke up and passed out without doing any damage.

The first floating ice appeared at Hannibal on December 7 and the river became frozen above the Wabash bridge on December 9, without forming any gorge, worth mentioning. At this point the river continued frozen over until 4.45 a. m. February 16. People crossed the river on this ice as late as February 11.

Below the Wabash bridge the ice formed and extended out from the shores and closed about a mile below town on December 17. Most of this ice went out on December 20, but soon re-formed and by December 30 the river was entirely frozen over below as well as above the bridge, except a small air hole just below the bridge. Below the bridge, people crossed the river on the ice from December 30 to February 9. This ice broke up and moved out on February 14 and the ice above the bridge began moving out on February 16.

There was heavy floating ice in the river from February 16 to February 23, but from that time to March 6 only a little ice was observed.

The greatest thickness of ice observed was 17 inches on January 28. It probably was a little thicker during the first few days of February, but no measurements were obtained.

At other places in this river district the conditions were about the same as at Hannibal.—*B. L. Waldron, Meteorologist in Charge.*

### *Memphis, Tenn., river district.*

The amount of ice passing through the Memphis district of the Mississippi River during the winter months of 1917–18, is believed to have been the greatest since the establishment of this station in 1871. Ice began moving past Memphis as early as December 13, 1917, and continued in varying amounts during most of the time until February 10, 1918. During December the river at times was nearly filled with moving ice, but not until the end of the month was there sufficient to interfere seriously with the movement of river craft, but on the 31st the ice became so heavy that only the largest boats attempted to run. Then on January 6, 1918, the ice gorged in a narrow stretch in the river near Richardson Landing about 50 miles above Memphis, causing a complete suspension of navigation to the north, but continued to southern points until January 17 when a portion of the Richardson gorge broke away, and this with the ice forming below the gorge filled the river from bank to bank, and on account of the low stage of water, a garge was formed about two miles below Memphis. For two or three days there was no movement in the ice at this place while the amount was constantly increasing from the flow from points above which, with the rapid increase in the water held back by the gorge, so increased the strain during the early morning of the 20th, that the gorge gave way and the whole mass moved out carrying with it four of the Lee Line steamers that were unable to reach a safe harbor on account of the ice congestion. Two of these steamers were crushed and sunk a few miles below Memphis while the remaining two were finally saved. Also a small steamer attached to the Mississippi River Commission fleet and one barge was sunk by the ice. From this time on to the end of January, 1918, only a moderate amount of ice passed Memphis as the Richardson gorge still held.

The Richardson Landing gorge extended a length of several miles, and at the point of formation reached from the river bed 4 to 10 feet above water level. At 12:30 p. m. February 4, 1918, this gorge gave way under the great pressure of added ice and water and seven hours later, about 7 p. m. the van of this ice gorge reached Memphis, filling the river from shore to shore with an immense mass of rough and jagged ice moving rapidly, some of the piled up cakes forming hummocks 10 to 15 feet in height. The Richardson Landing gorge held practically intact 29 days. On February 5, soon after midnight the great Osceola, Ark., gorge (see Fig. 8) that extended from a little below Osceola northward over 25 miles and first formed January 14, 1918—broke with a loud report that was heard for several miles. This ice reached Memphis at 9 a. m. and before noon the river was again filled with a turbulent mass of rapidly moving ice which imprisoned numerous small river craft, in all about 35 passing this station, some in perfect condition and some crushed and sinking. The craft passing here were: Twenty-one barges, a few laden but most of them empty; 2 wharf boats; 4 house boats; 1 dry-dock; 1 ferryboat; one pile driver; 1 tie loader; an unfinished hull of a steamer; and a few others of undetermined character. The unfinished hull is said to have come from Paducah, Ky. It is thought that most of these craft were saved before reaching Helena as only a few passed that place. There were two barges loaded with logs, one of which was smashed on one of the bridge piers at Memphis, while the other passed on safely. Except the loss of the two Lee Line steamers and two small ones, the property of the Mississippi River Commission, there was no local loss or damage to river craft owned or controlled in the Memphis district. This was due to the fact that all local craft, except the fleet of Government dredge boats safely moored in their harbor below the two railroad bridges, were brought into the new canal that now passes in front of the city, an extension of Wolf River that formed a safe refuge against the moving ice and prevented the destruction of at least $600,000 worth of river craft. Total damage in this district $115,000.

The Weather Bureau records show that serious ice conditions prevailed in the Mississippi in this district during the winter of 1872–3, which at that time was said to have been the coldest and most severe winter in the last 30 years. On December 27, 1872, a gorge that had formed at Randolph, Tenn. (practically the same place as Richardson Landing where the gorge of this year occurred) broke and out of 20 steamers at the Memphis harbor, 8 were totally destroyed and 7 badly damaged. The Brown & Jones Coal Co. lost coal then valued at $150,000. On December 30, 1876, another gorge occurred at Randolph, Tenn., causing a suspension of navigation; and again in January, 1877, a gorge formed at the same place. In January, 1887, navigation was suspended for 10 days on account of ice gorges.—*S. C. Emery, Meteorologist in Charge.*

### *Vicksburg, Miss., river district.*

Heavy floating ice began passing in the Mississippi River at Vicksburg during the night of January 20–21, 1918. On the 22d and 23d, the heavy ice was frozen together along each shore for about one-third of the way across, and the balance was moving. On the 24th, 25th, and 26th, the ice was all moving, and on the 27th, practically all had disappeared. Navigation was greatly impeded from January 21 to 25, inclusive. A little of the ice reached Natches, Miss., on January 24.

Heavy floating ice began passing on the night of February 9–10, and the flow of heavy ice practically ended during the night of 10–11. This was gorge ice from the Richardson and Osceola gorges above Memphis, Tenn. Navigation was impeded on the afternoon of February 10 by floating ice and débris.—*William E. Barron, Meteorologist in Charge.*

## NORTHERN TRIBUTARIES OF OHIO AND LAKE ERIE DRAINAGE.

### *Wabash river district.*

Ice formed in the river during the early days of December and by the 10th of the month the stream was frozen generally from source to mouth. Cold weather continued with very little interruption and by February 1 the ice was 13 to 14 inches thick in the extreme upper stream, 9 to 10 inches in the central portion, and 6 to 7 inches in the lower. After the first five days of February the weather became warmer, then thawing resulted, so that by the time the ice broke up, on February 12, it was from ½ to 1 inch less in the thicknesses than it was on the first of the month.

The ice broke up at Terre Haute, Ind., in the lower river late in the afternoon of February 11, but the general breaking up did not occur until the afternoon of February 12. On the morning of February 13 the stream was full of ice at all points. Gorging at some points occurred on the 13th and 14th, but this was slight and attended by little damage. In fact jamming and gorging did not reach a point where it caused any unusual concern; these conditions occurred in a much less degree than was anticipated.

By February 15 there was no ice in the upper river and this condition prevailed in the lower stream by the 19th. No ice was observed in the river at Terre Haute on the 17th and for 36 hours before there was only a small amount noticed.

In the upper stream in the vicinity of Bluffton a few shots of dynamite were used on February 11 and 12 with the view of protecting railroad and traction company bridges. No bridges were damaged, nor was any other material damage done, in the Wabash; a few small bridges that span some of the tributaries of the Wabash were damaged more or less, but no reliable information is available with respect to these.

It is estimated that $5,000 will cover all damage from ice in the entire valley.[1]—*W. P. Cade, Meteorologist in Charge.*

### *Fort Wayne, Ind., river district.*

During the early part of December, 1917, the weather was specially favorable to the formation of ice, particularly between the 6th and 16th, and much ice formed during that period on the Maumee and its tributaries. Moderately high temperatures from December 19 to 24 resulted in considerable thawing and the ice lost considerably in thickness; but from the closing days of December, 1917, until February 5, 1918, the weather was unusually favorable to a rapid and substantial increase in the thickness of the ice cover. The ice attained its maximum thickness on February 4 or 5, and on these dates, except at Fort Wayne, where the Maumee did not freeze entirely across during the winter, the general thickness of the ice ranged from 20 to 25 inches.

[1] Conditions on White River in Indiana, were much similar to those on the Wabash.—*A. J. H.*

The snow cover at the close of January, 1918, was unusually large throughout the Maumee watershed, and moderately warm weather and frequent rains subsequent to February 7 resulted in intense thawing. The surface run-off was large, the streams responded rapidly with increased stages, and the ice cover diminished and disintegrated quickly. In the upper reaches of the Maumee the ice began to break up on the 11th, but in the lower sections of the valley disintegration did not begin until the 12th or 13th. Gorges formed quite generally at upstream points on February 11 or 12, and at places east of Fort Wayne on the 12th or 13th. The gorges began to break up, as a rule, on February 14, except in Maumee Bay, where the final break up did not occur until March 3.

There was no flooding due to gorges at points above Defiance, Ohio; but from Napoleon, Ohio, eastward to Toledo, Ohio, the lowlands along the Maumee were inundated. On February 14 the water from the Maumee backed up to 19.5 feet at Napoleon, or 7.5 feet higher than would have occurred under normal conditions. Gorged conditions at Toledo caused the river to be above dock line from February 15 to 18, the maximum stage being 8.5 feet above the normal.

Detailed statements regarding the various gorges follow:

*Montpelier, Ohio, St. Joseph River.*—The ice at Montpelier was about 25 inches thick; it began to break up on February 14, and by the morning of the 15th the ice had moved downstream; the channel was free of ice and no gorge formed.

*Fort Wayne, Ind., St. Joseph River.*—A gorge formed at Tennessee Avenue bridge during the night of February 12 and extended a considerable distance upstream; the ice was from 12 to 18 inches thick, and by the morning of February 13 the gorge had disappeared; no damage resulted.

*Fort Wayne, Ind., St. Marys River.*—During the night of February 11 the ice began to break up on the St. Marys River and a gorge formed at Clinton Street bridge. The jammed ice extended upstream to Swinney Park, a distance of more than a mile; the gorge broke up and moved out at 12:15 p. m. February 14. The ice ranged from 10 to 20 inches in thickness. There was no damage.

As far as can be ascertained the ice moved freely down stream between Fort Wayne and Defiance, Ohio.

*Defiance, Ohio, Auglaize River.*—Between February 13 and 15 several gorges formed in the Auglaize. The most important of the gorges formed above the power dam and extended about 1 mile upstream. This gorge moved out on the 15th.

*Napoleon, Ohio, Maumee River.*—During the night of February 12 the ice in the shallow waters around Dependence Dam and Florida broke up and began to move downstream, gorging about 2 miles west of Napoleon. About 9:30 a. m. of the 13th the ice began to move out at Napoleon and gorged at the islands 1¼ miles east of Napoleon. The gorge held until 2:30 p. m. of the 13th, when it started to move out; it then jammed at Texas, Ohio, the water backing up to Napoleon, where a stage of 19.5 feet was attained at 8 a. m. of the 14th. At 10 a. m. of the 14th the gorge broke up and moved down the river. The ice was very dense and ranged from 16 to 24 inches in thickness. Although the flood waters covered a considerable area in the vicinity of Napoleon, the damage sustained was slight, as precautions had been taken to remove movable property to a place of safety.

Mr. W. S. Currier, official in charge of the Weather Bureau office at Toledo, Ohio, has furnished the following statement regarding ice and gorged conditions there.

"Ice began to form here along the shores of Maumee River and Bay on December 6, and by the 9th the river and probably much of Maumee Bay were frozen over. By the 17th of December the river ice averaged 8 inches in thickness and was reported to be 10 to 12 inches on the bay, but on the 24th the river ice was partially broken, due to the movement of tugs, and it only ranged from 2 to 4 inches in thickness where it had not been broken. Maumee Bay ice was from 7 to 9 inches thick on the 24th, but it was covered with water. After December 24 the ice on Maumee River and Bay increased in thickness until about February 4, 1918, ranging from 9 to 12 inches on the river and bay on January 14, and from 12 to 16 inches on January 21, reaching a maximum on February 4 of 18 to 22 inches on the river and 24 inches or more on the bay.

"After February 7 there was a rather rapid decrease in the ice covering the river and a slower decrease on the bay, the range in thickness on the river being from 9 to 12 inches on February 12, and the break-up began on February 14, due to rains in the valley and the coming down of ice from above. The ice opposite and below the city did not move to any extent, except to gorge in places, for some time after the break-up, as the bay ice held firm and prevented such movement. Maumee Bay ice broke on March 2 and 3 and moved out, allowing the ice in the river which had not previously disintegrated to move out, and all the ice of consequence was gone by the afternoon of March 4.

"From the 15th to the 18th of February the water in the river was above the dock line, due to gorged ice, the extreme height being about 8.5 feet above normal, and some damage and much inconvenience resulted from the water on Water Street and the flooding of many cellars for several blocks from the river. By February 27 the packed ice had disintegrated to such an extent that there were many open places and the river channel was partially open down to near the bay."—*P. McDonough, Meteorologist in Charge.*

### *Columbus, Ohio, river district.*

Notwithstanding the large quantity of ice that necessarily formed in the rivers of Ohio during the abnormally cold weather of the winter of 1917–18, it all passed out without damage of consequence at any point. In fact it would seem hardly possible for the rivers to clear themselves of ice with less damage. The ice began to break up and to move on February 9 and by the 12th was practically all out; at least all danger was past. The ice varied in thickness from about 12 to 20 inches.—*W. H. Alexander, Meteorologist in Charge.*

### *Dayton, Ohio, river district.*

The Miami River and its tributaries became frozen on December 9, 1917, and were not free of ice until February 14.

The ice began breaking in the upper portion of the Miami February 9, and at Dayton on the 10th; and from the 10th to the 13th numerous gorges and ice dams formed in the main river and in the Stillwater.

On the 10th and 11th small gorges formed at Sidney, Ohio, one at the county bridge just south of the city and the other at the Baltimore & Ohio Railway bridge. The ice in these did not exceed 3 or 4 feet, and it passed out without doing any material damage.

A small gorge formed at Piqua against the unbroken ice, accumulating to a thickness of about 4 feet. This broke and passed out the night of the 10th without causing any marked rise in the water and without doing any damage.

On the 13th an ice dam formed at Tadmore, causing the water to rise 1 foot above the flood stage. Some farm land in the vicinity was flooded, but no damage resulted.

In the evening of the 10th the ice began collecting at Fifth Street, Dayton, Ohio, against a temporary bridge in use since the 1913 flood. About 9:30 a. m. of the 11th this structure gave way and was completely destroyed. The damage was not great, however, as the new permanent bridge was completed and ready for traffic about two days later.

About 10 a. m. of the 11th a gorge formed against the unbroken ice below the Main Street bridge, on which the gage is located, and held till about 1 p. m. This caused a rise of over 2 feet at the gage, but the ice passed out without doing any damage.

About 11 a. m. of the 12th a gorge formed at the Baltimore & Ohio bridge just above this city, and carried away a temporary structure which was in use while repairs were being made and one pier of the bridge. All traffic over the bridge was stopped for three days.

Several ice dams formed at West Milton on the Stillwater, beginning the morning of the 11th. The most important one was on the 12th and 13th. The dam extended for more than half a mile up and down the river and its thickness was estimated at 6 to 10 feet. At 5 p. m. of the 12th the water rose to a height of 17 feet which is 5 feet above the flood stage.

The dam went out the night of the 12th and the river fell quickly to a stage several feet below flood stage.

A few farms were flooded, but the damage was slight.—*R. F. Young, Meteorologist in Charge.*

## ATLANTIC DRAINAGE.

### SUSQUEHANNA RIVER.

### *Harrisburg, Pa., river district.*

Some of the small streams on the Susquehanna River system became frozen during the latter part of November and by December 10 the river and its tributaries were generally icebound. The weather continued cold until near the end of the first week in February. January, 1918, was the coldest January at Harrisburg since the station was established, the mean temperature for the month being 19.1° or 9.6° below the normal. The ice on the streams increased gradually, the thickness on the rivers and creeks ranging from about 18 to over 36 inches. On account of the continued cold little or no snow water found its way into the streams. The "January thaw" that many people talk so much about did not occur and the snow continued to increase in the watershed. On January 30 the average depth of snow in the vicinity of Harrisburg was 24 inches, probably the greatest amount on the ground at any time in the last 30 years or more. The streets were packed with ice and snow to a depth of 2 feet or more and many of the narrow streets were impassable. Snow was piled along the curbs to a depth of 3 to 6 feet.

High temperature on February 7 caused the snow to decrease rapidly in depth, and by the 11th some streams began to rise. Ice movements began on the Juniata and Chemung Rivers on the night of February 12, that from the Juniata gorging at the mouth of the river near Duncannon. This gorge, which was 10 to 15 feet high, damaged the piers of the bridge at Juniata, destroyed two or three buildings and damaged others. As a

result of this gorge traffic was suspended on the Juniata highway bridge which crosses the Juniata River near its mouth to Duncans Island, and also on the covered highway bridge at Clarks Ferry, which spans the Susquehanna from Duncans Island to the eastern shore. The Chemung ice broke at Corning about 3 a. m. of the 13th and moved slowly down the river, forming ice jams, which broke as the water accumulated behind them, re-formed and broke again. Frank Gray and two boys who were with him narrowly escaped drowning, being caught by the ice flood on the flats between Lowman and Wellsburg while driving a team. They were finally rescued by men in boats. The horses also were saved. This ice flood reached Towanda on the night of the 13th, the ice breaking there about 9 p. m. of that day and moving out on a stage of about 13 feet. It reached Wilkes-Barre on the night of the 14th, passing on a stage of about 18 feet. The flood water from the Juniata gradually lifted the ice in the Susquehanna River below Duncannon, the break at Harrisburg occurring at 3:15 a. m. of the 15th on a stage of about 11 feet. The ice from the Chemung River and the North Branch below Athens reached the main river early on the morning of the 16th and began to pass Harrisburg about 3 p. m. of that date, the river reaching a maximum stage of 15.2 feet at 6 p. m. This flood lifted the gorge at the mouth of the Juniata and all the ice from the Juniata, Chemung, and the North Branch, together with most of that in the main river below Sunbury, lodged at Pequea, a short distance below the mouth of Conestoga Creek, about 55 miles below Harrisburg, forming a great gorge said to have been 20 or more feet in thickness and several miles long. This gorge caused serious flooding at Safe Harbor and vicinity, the railroad tracks there being several feet under water and ice for three or four days.

The ice in the West Branch broke at Clearfield at 1 p. m. on February 13, the river there reaching a maximum stage of 9.4 feet, slightly above flood point. At Renovo the break occurred about 4:30 p. m. of the 13th. The ice continued to move slowly, piling up and breaking and finally lodging, jamming the channel from Jersey Shore almost to Lock Haven with a gorge said to range in thickness from 10 to about 20 feet. Following a short period of warm weather with rain on the 19th and 20th, the water rose behind the gorge at Jersey Shore, causing serious flooding at points above, particularly at Lock Haven, where the water reached a stage of about 21 feet, flooding the railroad tracks to a depth of several feet and causing the suspension of all trains on the Northern Central and New York Central Railroads. The water covered most of the town to a depth of several feet. Some houses in the lower part of the city had water almost to the second floor. A cold wave with zero temperature on the night of the 20th caused the water in the houses to freeze to a thickness sufficient to permit people to skate on it. The light plant was flooded, and the people were without light and in many cases without fuel. The mayor of Lock Haven appealed for help, which was speedily furnished, but much suffering and some sickness resulted and the damage to property was great. The lower part of the Jersey Shore gorge broke on the night of February 20, passing Williamsport on a stage of 21.4 feet, 1.4 feet above the flood point. This break did not immediately relieve the serious situation at Lock Haven, as the upper part of the gorge held until about 3.30 p. m. of the 21st. During the 15 minutes following this break the water fell 4 feet on the Lock Haven gage. The ice from the West Branch began to pass Harrisburg during the afternoon of the 21st, the river reaching a maximum stage of 14.1 feet at 3 a. m. of the 22d and remaining stationary until afternoon, when it began to fall slowly. This flood opened a channel on the west side of the river at Pequea, and the river there fell rapidly on the 22d. Probably many small gorges or jams formed of which no information was received. The greatest damage to property occurred behind the Jersey Shore gorge, principally at Lock Haven, where it probably amounted to $100,000. Many highway bridges were damaged and a few were destroyed, and some railway bridges were damaged. The Pennsylvania Railroad bridge crossing Conestoga Creek near Pequea sank about 2 feet while a freight train was crossing it soon after the gorge broke.

An accurate estimate of the damage caused by ice floods is impossible, but it is believed it is conservative to say that the loss in the Susquehanna watershed was at least $300,000.

Considering the great accumulation of snow and the thickness of ice on the streams the damage was much less than might have been reasonably expected under the circumstances. A general and heavy rain over the watershed with high temperatures would have caused a disastrous flood. Actually but few places suffered, and the waters reached flood stage only over comparatively short stretches.—*E. R. Demain, Meteorologist in Charge.*

### DELAWARE AND SCHUYLKILL RIVERS.

### *Philadelphia, Pa., river district.*

Early in February, 1918, there was a snow covering of about 30 inches over the headwaters of all of the streams. The snow was solid and held a large water content, being the accumulations of the December and January snows.

It so happened that the snow melted a little at a time in three or four periods, and without rains of consequence; so that the ice, which was the heaviest in many years, broke up and passed out with comparatively little obstruction and with no material damage. Jams were reported in the Lehigh River at the Parryville dam and at Treichler's, but neither was of a serious character. A large amount of ice backed up in the Schuylkill at Philadelphia, but passed out on a sudden rise and without damage. The East Branch of the Delaware at Fishs Eddy, N. Y., rose to 16 feet on the 20th (the flood stage being 10 feet), but the water and the ice passed out with only slight damage. At Hale Eddy, N. Y., on the West Branch of the Delaware, the water rose to 13.4 feet on the 20th (flood stage being 12 feet). These waters seemed to spread out farther down the river, and at Port Jervis the highest stage was 9 feet (flood stage being 18 feet), while at Phillipsburg (junction of the Delaware and Lehigh) there was a stage of 15 feet on the 21st, or 7 feet below the flood stage.

The Schuylkill rose high enough at Manyunk, Philadelphia, on the 21st to temporarily suspend operations in several mills. Warnings were given to the police department on the 20th and movable property was taken care of. These were the only warnings issued and were the only ones practicable.—*George S. Bliss, Meteorologist in Charge.*

### POTOMAC RIVER.

A short spell of mild temperature with light rain on February 10 melted much of the snow in the watershed above Washington, D. C. Mild temperature on the 11th and 12th, without rain, caused a break-up in the ice on the 12th from Cumberland, Md., to below Harpers Ferry, W. Va.

### *Washington, D. C.*

*February 13, 1918.*—Ice broke up at 2:00 a. m. and a gorge formed from Chain Bridge nearly to the Aqueduct Bridge, gorged from Rock Creek to Highway Bridge; water 6 feet above bank at Chain Bridge and ice left 6 feet deep from river to canal bank. Gorges broke in places during the day and reformed at night. A firm gorge formed against Acqueduct Bridge during the night of February 13–14 and extended to Highway Bridge on the District of Columbia side. The old channel on the Virginia side of Analostan Island cleared about 5.00 a. m. and allowed the flow of the river to go by that channel. Before the old channel on the Virginia side cleared, the ice was piled up 3 to 4 feet above the river wall at the gage, Twenty-seventh and G Streets, and would probably have gone 5 feet higher if the Virginia channel had not cleared. The water was 3.5 feet deep on K Street and Thirty-first Street, but stores were not flooded below Eighth and Pennsylvania Avenue.

*February 16, 1918.*—Some small gorges still held between Chain Bridge and Aqueduct Bridge.

*February 18, 1918.*—Channel on District of Columbia side cleared from Acqueduct Bridge to Highway Bridge. All house boats on the river were crushed by the ice and all boat houses, except three, were practically destroyed. Many dredges were carried down the river, but most of these were recovered later.

Loss to house-boats estimated at $1,500.

Loss to boathouses estimated at $15,000.

Loss to barges, stores, and business houses on K Street estimated at $38,200.—*A. J. Henry, Meteorologist in Charge.*

### JAMES RIVER.

### *Richmond, Va., river district.*

The winter of 1917–18 to date has been unusually severe. Temperatures low enough to form ice on the various rivers of the State, were general in the latter part of November and from that time on until early in February, they continued low. In the river district under the supervision of this office (James River) the ice steadily increased in thickness during December, 1917, the coldest month of that name of record in this State, and also through January, 1918, and it was not until January 26, 1918, that the day temperatures became high enough to cause melting of the ice.

On this date, also, a six-day period of precipitation, which came partly as rain and partly as snow or sleet, set in. Fortunately, however, the night temperatures during this period were at freezing, or below, and this checked the run-off and prevented any sudden rise in the river and breaking up and gorging of the ice. From the close of January to February 6 freezing weather kept the ice intact, but on the last-named date the day temperatures rose and a general and decided thaw set in, checked as before by cool nights. The snow cover in the watershed, which was practically continuous from the middle of December until this time, and unusually heavy, disappeared rapidly and the resulting run-off soon reached the James, lifting the ice and starting it downstream. The situation thus became full of danger and was a source of anxiety to this office, and the people of the cities and

towns along the river bank. Ice gorges formed on February 8 at Indian Rock and Sabot; on the 9th at Glasgow; and on the 10th at Colemans Falls and Hatton, with ice reported to be from 18 inches to 2½ feet thick, which piled up at some points to a height of 6 feet or more above the water. A continued though slow rise in the river broke these gorges on the last-named date and they moved downstream to tidewater, being further broken in this passage over various shoals and rapids. These fields of broken ice passed by Richmond for several days prior to February 12, when the river was clear here, but they lodged again at Dutch Gap, about 25 miles below this city, and interrupted navigation on the 12th.—*E. A. Evans, Meteorologist in Charge.*

SUMMARY.

The essential facts established by the foregoing reports are as follows: A period of excessively cold weather set in in December, 1917, and continued without important moderation until about the first of February, 1918. The extreme minima for the time and place during a period of almost half a century were reached in localities throughout the Ohio Valley. It is probable that a low minimum temperature is not so effective in causing ice formation as consecutive nights of temperatures below a certain value which may be called the critical minimum. In the vicinity of Washington, D. C., a minimum temperature of 20° F., in a thermometer shelter, on three consecutive nights will cause ice several inches in thickness to form in streams of running water. The mean minimum temperature at Cincinnati, Ohio, December, 1917, was 13.9° F.; January, 1918, 8.3° F.

As a result of this long period of low temperature the ice in the pools along the streams attained great thickness and continued firm throughout the cold period. The gorged ice likewise became solidified and capable of great resistance to pressure from upstream. The break-up began on the southern tributaries of the Ohio as the direct result of moderate rains, separated by an interval of but 24 hours. The temperature at the time of the rain was not greatly above the freezing point, and it remained above freezing but a short time; consequently there was no opportunity for the ice to become soft and honeycombed. As a result the ice which passed into the Ohio from southern tributaries, and that which broke up in the main stream, was unusually firm and in great cakes. Some idea of the size of the cakes may be had from fig. 7.

The northern tributaries of the Ohio remained firm during the critical period and contributed very little water to the trunk stream.

The ice in the trunk stream broke up in sections and on moderately low stages. It is probable that the low stages and the reduced velocity of the current was a factor in conserving the size of the ice blocks and in preventing a material reduction in the ice floes by attrition.

The loss, including suspension of business, due to the breaking up and passing out of the ice, summarized by districts, follows:

| | |
|---|---|
| Pittsburgh, Pa. | $300,000 |
| Parkersburg, W. Va. | 9,600 |
| Cincinnati, Ohio | 1,988,000 |
| Louisville, Ky. | 365,000 |
| Evansville, Ind. | 127,905 |
| Cairo, Ill. | 421,700 |
| Total for the Ohio | 3,212,205 |

It seems to have been the almost universal experience along the river, that the winter mooring places of river craft were unsafe when the break-up in the ice came. The only exception was at Louisville, Ky., where it is reported that craft totaling $1,000,000 in value found safety in the Portland Canal.

The loss on the Mississippi due to ice gorges while not so heavy as in the lower Ohio was yet considerable. See report of S. C. Emery, of the Memphis, Tenn., district (p. 92).

The final break-up of ice in the northern tributaries of the Ohio and the Mississippi above St. Louis was accomplished without serious damage or loss due, it is believed, largely to the fact that the ice in those streams had become more or less honeycombed and soft by spells of thawing weather in February. At the close of that month the ice had not yet gone out of the Missouri above Omaha, Nebr., although its condition promised an early break-up. By March 11 the river was open to Sioux City, Iowa.

At the end of February the Mississippi was practically free of ice south of Davenport, Iowa. Ice at that place went out on March 2, and by March 12 the ice had broken up as far north as St. Paul, although the river at La Crosse, Wis., had not yet cleared.

The Hudson was free of ice at Albany and Troy, N. Y., also the lower Mohawk; but ice still held above Schenectady and in the lower Hudson. The upper reaches of New England streams were icebound at the close of the month.

# SECTION V.—SEISMOLOGY.

## SEISMOLOGICAL REPORTS FOR FEBRUARY, 1918.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., April 5, 1918.]

TABLE 1.—*Noninstrumental earthquake reports, February, 1918.*

| Day. | Approximate time, Greenwich Civil. | Station. | Approximate latitude. | Approximate longitude. | Intensity Rossi-Forel. | Number of shocks. | Duration. | Sounds. | Remarks. | Observer. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1918. | *H. m.* | CALIFORNIA. | ° ′ | ° ′ | | | *M. s.* | | | |
| Feb. 11 | 22 45 | Bishop | 37 23 | 118 24 | 5 | 1 | | Rumbling | Abrupt bump, S-N | E. M. Nordyke. |
| 24 | 00 12 | Eureka | 40 48 | 124 11 | 4 | Several. | 0 01 | None | Rapid rocking, W-E | U. S. Weather Bureau. |
| | | ILLINOIS. | | | | | | | | |
| 17 | 8 10 | Cairo | 37 00 | 89 10 | 3 | 1 | 0 02 | Faint | Abrupt rocking, E-W | J. F. McGruder. |

TABLE 2.—*Instrumental reports, February, 1918.*

[Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.]

[For significance of symbols see REVIEW for January, 1918, p. 34.]

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. J. W. Green.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

| Instrumental constants... | | *V* | $T_0$ |
|---|---|---|---|
| | E | 10 | 16.7 |
| | N | 10 | 15.4 |

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | *H. m. s.* | *Sec.* | $\mu$ | $\mu$ | *km.* | |
| 1918. Feb. 13 | ..... | $e_E$ | 5 31 13 | ..... | ..... | ..... | ..... | Microseismic tremors on Feb. 12 and 26. No earthquakes recorded during January. |
| | | $e_N$ | 5 31 42 | 4 | ..... | ..... | ..... | |
| | | $eL_N$ | 5 41 32 | 30 | ..... | ..... | ..... | |
| | | $M_N$ | 5 52 52 | 16 | ..... | 60 | ..... | |
| | | $M_E$ | 5 54 53 | ..... | 10 | ..... | ..... | |
| | | C | 6 03 .. | ..... | ..... | ..... | ..... | |
| | | F | 6 14 .. | ..... | ..... | ..... | ..... | |

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat. 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

| Instrumental constants... | | *V* | $T_0$ |
|---|---|---|---|
| | E | 10 | 13.9 |
| | N | 10 | 19.1 |

| 1918. | | | *H. m. s.* | *Sec.* | $\mu$ | $\mu$ | *km.* | |
|---|---|---|---|---|---|---|---|---|
| Feb. 12 | ..... | $eP_E$ | 1 25 24 | ..... | ..... | ..... | ..... | |
| | | $eL_E$ | 1 25 36 | ..... | ..... | ..... | ..... | |
| | | $eP_N$ | 1 25 50 | 2 | ..... | ..... | ..... | |
| | | $eL_N$ | 1 26 08 | ..... | ..... | ..... | ..... | |
| | | $M_E$ | 1 26 08 | 11 | 120 | ..... | ..... | |
| | | $M_N$ | 1 26 16 | 12 | ..... | 150 | ..... | |
| | | C | 1 34 .. | 5 | ..... | ..... | ..... | |
| 12 | ..... | eL | 1 39 20 | ..... | ..... | ..... | ..... | |
| | | $M_E$ | 1 39 36 | 8 | 10 | ..... | ..... | |
| | | $M_N$ | 1 39 45 | 8 | ..... | 40 | ..... | |
| | | C | 1 43 .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | eL | 2 05 .. | 10 | 10 | 10 | ..... | |
| | | C | 2 08 .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | $eL_E$ | 19 19 02 | ..... | ..... | ..... | ..... | |
| | | $eL_N$ | 19 19 08 | ..... | ..... | ..... | ..... | |
| | | $M_N$ | 19 19 32 | 12 | ..... | 110 | ..... | |
| | | $M_E$ | 19 19 45 | 10 | 80 | ..... | ..... | |
| | | F | 19 28 .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | $eL_N$ | 19 30 38 | ..... | ..... | ..... | ..... | |
| | | $eL_E$ | 19 30 52 | ..... | ..... | ..... | ..... | |
| | | $M_N$ | 19 31 32 | 9 | ..... | 60 | ..... | |
| | | $M_E$ | 19 32 24 | 8 | 50 | ..... | ..... | |
| | | F | 19 36 .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | $eP_E$ | 20 04 52 | 2 | ..... | ..... | ..... | |
| | | $eP_N$ | 20 05 19 | 2 | ..... | ..... | ..... | |
| | | $eL_E$ | 20 05 20 | ..... | ..... | ..... | ..... | |
| | | $eL_N$ | 20 05 31 | ..... | ..... | ..... | ..... | |
| | | M | 20 05 40 | 5 | 710 | 590 | ..... | |
| | | C | 20 07 .. | ..... | ..... | ..... | ..... | |
| | | F | 20 16 .. | ..... | ..... | ..... | ..... | |

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121°38′ 34″ W. Elevation, 1,281.7 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

| 1918. | | | *H. m. s.* | *Sec.* | $\mu$ | $\mu$ | *km.* | |
|---|---|---|---|---|---|---|---|---|
| Feb. 5 | ..... | ..... | ..... | ..... | 100 | 100 | ..... | Microseisms during 24 hours preceding 16 hours G. M. T. on dates given. |
| 20 | ..... | ..... | ..... | ..... | 100 | 100 | ..... | |

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 03″ W. Elevation, 27.43 meters.

(See record of the Seismographic Station, University of Santa Clara.)

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

| 1918. | | | *H. m. s.* | *Sec.* | $\mu$ | $\mu$ | *km.* | |
|---|---|---|---|---|---|---|---|---|
| Feb. 5 | ..... | $eL_E$ | 24 .. .. | ..... | ..... | ..... | ..... | Wavelets. |
| 6 | ..... | $F_E$ | 3 .. .. | ..... | ..... | ..... | ..... | |
| 16 | ..... | $eL_E$ | 16 10 00 | ..... | ..... | ..... | ..... | Wavelets, thickening of pen marks. |
| | | $F_E$ | 19 15 .. | ..... | ..... | ..... | ..... | |
| 26 | ..... | $eL_E$ | 16 40 .. | ..... | ..... | ..... | ..... | Doubtful as to being seismic. Heavy machinery in motion nearby. |
| | | $F_E$ | 16 55 .. | ..... | ..... | ..... | ..... | |
| 27 | ..... | L | 22 32 .. | ..... | ..... | ..... | ..... | Frequent wavelets and thickening of pen marks on both components during day. |
| | | F | 22 36 .. | ..... | ..... | ..... | ..... | |
| 28 | ..... | $eL_E$ | 21 24 .. | ..... | ..... | ..... | ..... | Distinct activity on E-W during day. Most prominent at hour marked. |
| | | $F_E$ | 21 26 .. | ..... | ..... | ..... | ..... | |

TABLE 2.—*Instrumental reports, February, 1918*—Continued.

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| **District of Columbia. *Washington. U. S. Weather Bureau.*** Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters. Instrument: Marvin vertical pendulum, undamped. Mechanical registration. Instrumental constants.. $V$ 110, $T_0$ 6.4 | | | | | | | | |
| 1918. Feb. 3 | ..... | $eL_{EN}$... | *H. m. s.* 14 58 30 | *Sec.* | μ | μ | *km.* | Amplitude very small. |
| | | F..... | 15 07 .. | | | | | |
| 4 | ..... | eL?... | 20 54 .. | | | | | Heavy microseisms. |
| | | F..... | 21 .. .. | | | | | Phases undiscernible. |
| 12 | ..... | e?..... | 1 31 .. | | | | | |
| | | L..... | 1 45 05 | 10 | | | | |
| | | F..... | 2 .. .. | | | | | |
| 12 | ..... | e..... | 19 33 39 | | | | | F merged with following quake. |
| | | L..... | 19 34 35 | 12 | | | | |
| | | F..... | .. .. .. | | | | | |
| 12 | ..... | e..... | 19 45 25 | | | | | |
| | | L..... | 19 46 40 | 12 | | | | |
| | | F..... | 19 51 .. | | | | | |
| 12 | ..... | e..... | 20 18 50 | | | | | |
| | | L..... | 20 20 15 | | | | | |
| | | F..... | 20 35 .. | | | | | |
| 13 | ..... | eL..... | 3 57 30 | | | | | |
| | | F..... | 4 10 .. | | | | | |
| 13 | ..... | e..... | 6 27 30 | | | | | |
| | | eL..... | 6 43 45 | 40 | | | | |
| | | $L_{resp}$... | 7 02 30 | 32 | | | | |
| | | F..... | 8 .. .. | | | | | |
| 19 | ..... | e..... | 17 25 .. | | | | | |
| | | L..... | 17 28 .. | | | | | |
| | | F..... | 17 40 .. | | | | | |
| 24 | ..... | P..... | 23 06 39 | | | | | |
| | | S..... | 23 11 43 | | | | | |
| | | L..... | 23 17 27 | | | | | |
| | | F..... | 23 25 .. | | | | | |
| **District of Columbia. *Washington. Georgetown University.*** F. A. Tondorf, S. J. Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite. Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical. Instrumental constants: E $V$ 165, $T_0$ 5.4, ε 0; N 143, 5.2, 0; *Z* 80, 3.0, 0 | | | | | | | | |
| 1918. Feb. 3 | ..... | ..... | *H. m. s.* | *Sec.* | μ | μ | *km.* | Long waves show interruptedly from 14h 48m to 15h 14m. Periods variable. Heavy microseims. |
| 4 | ..... | eL..... | 20 54 00 | | | | | Very heavy microseisms. |
| | | F..... | 21 10 .. | | | | | |
| 12 | ..... | e?..... | 1 30 43 | | | | | Heavy microseisms. All phases except $eL_N$ difficult. |
| | | $eL_N$... | 1 41 24 | | | | | |
| | | F..... | 2 02 .. | | | | | |
| 12 | ..... | e..... | 19 33 37 | | | | | |
| | | $eL_N$... | 19 34 30 | 13 | | | | |
| | | F?..... | .. .. .. | | | | | |
| 12 | ..... | $eP_E$?.. | 20 15 10 | | | | | Microseisms. |
| | | $eP_N$?.. | 20 15 12 | | | | | |
| | | $iS_N$.... | 20 19 52 | | | | | |
| | | $iS_E$.... | 20 19 57 | | | | | |
| | | $eL_E$... | 20 21 24 | | | | | |
| | | $eL_N$... | 20 21 42 | | | | | |
| | | F..... | 20 50 .. | | | | | |
| 13 | ..... | $L_E$.... | 4 02 12 | | | | | Heavy microseisms. |
| 13 | ..... | | 4 08 .. | | | | | |
| | | e..... | 6 27 ca | | | | | Series of long waves from 7h 4m to 7h 35m. Heavy microseisms. |
| | | L..... | 7 04 15 | | | | | |
| | | F..... | 8 00 .. | | | | | |
| 18 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Series of long waves from 16h 53m to 17h 8m. Periods variable. Heavy microseisms. |
| 25 | ..... | $e_E$..... | 23 06 40 | | | | | Heavy microseisms. |
| | | $e_N$..... | 23 06 41 | | | | | |
| | | $L_N$..... | 23 12 29 | 8 | | | | |
| | | $L_E$..... | 23 12 33 | 8 | | | | |
| | | F..... | 23 25 ca | | | | | |

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| **Hawaii. *Honolulu. Magnetic Observatory.*** U. S. Coast and Goedetic Survey. Frank Neuman. Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters. Instrument: Milne seismograph of the Seismological Committee of the British Association. Instrumental constant.. $T_0$ 18.5 | | | | | | | | |
| 1918. Feb. 3 | ..... | eP..... | *H. m. s.* 14 16 54 | *Sec.* | μ | μ | *km.* | |
| | | eL..... | 14 19 48 | 20 | | | | |
| | | M..... | 14 21 30 | 20 | *500 | | | |
| | | C..... | 14 33 .. | | | | | |
| | | F..... | 15 32 .. | | | | | |
| 6 | ..... | eP..... | 3 24 00 | | | | | |
| | | eL..... | 3 27 42 | 19 | | | | |
| | | M..... | 3 35 06 | 17 | *100 | | | |
| | | C..... | 3 38 .. | | | | | |
| | | F..... | 4 23 .. | | | | | |
| 6 | ..... | eL..... | 14 59 00 | | | | | |
| | | M..... | 15 03 54 | 19 | *100 | | | |
| | | C..... | 15 08 .. | | | | | |
| | | F..... | 15 16 .. | | | | | |
| 7 | ..... | eP..... | 5 31 30 | | | | | |
| | | S..... | 5 41 00 | | | | | |
| | | M..... | 5 42 12 | | *1,800 | | | |
| | | eL..... | 5 54 12 | 19 | | | | |
| | | M..... | 6 05 00 | 17 | *1,000 | | | |
| | | C..... | 6 12 .. | | | | | |
| | | F..... | 7 23 .. | | | | | |
| 9 | ..... | eL..... | 21 11 24 | | | | | |
| | | M..... | 21 11 54 | | *100 | | | |
| | | F..... | 21 16 .. | | | | | |
| 13 | ..... | eL..... | 2 57 .. | | | | | |
| | | F..... | 3 55 .. | | | | | |
| 13 | ..... | eP..... | 6 29 06 | | | | | |
| | | eL..... | 6 43 00 | 27 | | | | |
| | | M..... | 6 53 18 | 18 | *4,000 | | | |
| | | C..... | 6 58 .. | | | | | |
| | | F..... | 9 44 .. | | | | | |
| 19 | ..... | eP..... | 16 36 24 | | | | | |
| | | eL..... | 16 42 00 | 27 | | | | |
| | | M..... | 16 49 00 | 20 | *1,500 | | | |
| | | C..... | 16 52 .. | | | | | |
| | | F..... | 17 55 .. | | | | | |
| 24 | ..... | eL..... | 23 23 54 | 19 | | | | |
| | | M..... | 23 26 30 | | *100 | | | |
| | | F..... | 23 30 .. | | | | | |
| 25 | ..... | eP..... | 6 18 30 | | | | | |
| | | eL..... | 6 26 12 | 23 | | | | |
| | | M..... | 6 29 00 | 19 | *100 | | | |
| | | C..... | 6 34 .. | | | | | |
| | | F..... | 7 11 .. | | | | | |
| 27 | ..... | eP..... | 3 29 00 | | | | | |
| | | eL..... | 3 39 00 | 19 | | | | |
| | | M..... | 3 42 06 | 19 | *200 | | | |
| | | C..... | 3 46 48 | | | | | |
| | | F..... | 4 09 .. | | | | | |

* Trace amplitude.

**Kansas. *Lawrence. University of Kansas.*** Department of Physics and Astronomy. F. E. Kester.
Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W.; Elevation, 301.1 meters.
Instrument: Wiechert.

Instrumental constants.. E $V$ 177, $T_0$ 3.4, ε 4:1; N 205, 3.4, 4:1

(Report for February, 1918, not received.)

TABLE 2.—*Instrumental reports, February, 1918*—Continued.

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.. E: V 10, $T_0$ 15; N: V 10, $T_0$ 15

| 1918. | | | H. m. s. | Sec. | μ | μ | km. | |
|---|---|---|---|---|---|---|---|---|
| Feb. 12 | ..... | $e_N$ | 1 40 49 | ..... | ..... | ..... | ..... | E not recording properly. |
| | | $M_N$ | 1 41 49 | 10 | ..... | 10 | ..... | |
| | | F | 1 50 .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | $eI'_N$ | 19 33 52 | ..... | ..... | ..... | ..... | |
| | | $eL_N$ | 19 34 40 | ..... | ..... | ..... | ..... | |
| | | $M_N$ | 19 34 55 | 12 | ..... | 10 | ..... | |
| | | F | 19 37 .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | e | 20 20 05 | ..... | ..... | ..... | ..... | |
| | | $M_N$ | 20 21 13 | 12 | ..... | 60 | ..... | |
| | | F | 20 27 .. | ..... | ..... | ..... | ..... | |
| 13 | ..... | $e_N$ | 7 05 .. | ..... | ..... | ..... | ..... | A series of long waves. |
| | | $M_N$ | 7 23 28 | 16 | ..... | 50 | ..... | |
| | | F | 7 42 .. | ..... | ..... | ..... | ..... | |

Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants.. E: V 80, $T_0$ 23, ε 0; N: V 50, $T_0$ 25, ε 4:1

(Report for February, 1918, not received.)

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants.. V 80, $T_0$ 7, ε 5:1

| 1918. | | | H. m. s. | Sec. | μ | μ | km. | |
|---|---|---|---|---|---|---|---|---|
| Feb. 12 | I..... | L..... | 1 35 24 | 12 | ..... | ..... | ..... | $P_E$ and $S_E$ masked by microseisms. $S_N$ doubtful. |
| | | F..... | 1 45 .. | ..... | ..... | ..... | ..... | |
| 12 | I..... | iS..... | 20 14 42 | ..... | ..... | ..... | ..... | P lost by local disturbances. |
| | | L..... | 20 15 24 | 6 | ..... | ..... | ..... | |
| | | F..... | 20 23 .. | ..... | ..... | ..... | ..... | |
| 13 | II.... | eL..... | 7 00 06 | 30 | ..... | ..... | ..... | |
| | | $L_N$..... | 7 06 30 | ..... | ..... | ..... | ..... | |
| | | $L_N$..... | 7 19 18 | ..... | ..... | ..... | ..... | |
| | | $L_N$..... | 7 22 42 | ..... | ..... | ..... | ..... | |
| | | F..... | 7 34 .. | ..... | ..... | ..... | ..... | |
| 14 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Record indicates seismic disturbances, but not readable on account of high wind disturbances. Microseisms present on 16th, 21st, 23d, 26th. |

New York. *Buffalo. Canisius College.* John A. Curtin, S. J.

Lat., 42° 53′ 02″ N.; long., 78° 52′ 40″ W. Elevation, 190.5 meters.

Instrument: Wiechert 80 kg. horizontal.

Instrumental constants.. V 80, $T_0$ 7, ε 5:1

(Report for February, 1918, not received.)

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|

New York. *Fordham. Fordham University.* W. C. Repetti, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants.. E: V 72, $T_0$ 6.6, ε 1.5:1; N: V 72, $T_0$ 7.1, ε 3.8:1

| 1918. | | | H. m. s. | Sec. | μ | μ | km. |
|---|---|---|---|---|---|---|---|
| Feb. 12 | ..... | $iP_N$ | 20 16 44 | ..... | ..... | ..... | ..... |
| | | $iP_E$ | 20 16 49 | ..... | ..... | ..... | ..... |
| 13 | ..... | eL | 6 59 00 | 22 | ..... | ..... | ..... |
| | | F | 7 23 00 | ..... | ..... | ..... | ..... |

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration).

Instrumental constants.. E: V 13, $T_0$ 22, ε 4:1; N: V 14, $T_0$ 25, ε 4:1

(Report for February, 1918, not received.)

Panama Canal. *Balboa Heights.* Governor, Panama Canal.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg.

Instrumental constants.. V 10, $T_0$ 20

| 1918. | | | H. m. s. | Sec. | μ | μ | km. |
|---|---|---|---|---|---|---|---|
| Feb. 20 | ..... | $P_E$ | 6 35 48 | ..... | ..... | ..... | 650 |
| | | $P_N$ | 6 35 52 | ..... | ..... | ..... | ..... |
| | | $L_N$ | 6 37 16 | 20 | ..... | *2,000 | ..... |
| | | $L_E$ | 6 37 20 | 20 | *2,000 | ..... | ..... |
| | | $M_E$ | 6 37 24 | ..... | ..... | ..... | ..... |
| | | $M_N$ | 6 38 46 | ..... | ..... | ..... | ..... |
| | | $F_E$ | 6 51 30 | ..... | ..... | ..... | ..... |
| | | $F_N$ | 6 53 .. | ..... | ..... | ..... | ..... |

* Trace amplitude.

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. L. Adams.

Lat., 18° 08′ 48″ N.; long., 65° 26′ 54″ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants.. E: V 10, $T_0$ 17.5; N: V 10, $T_0$ 18

| 1918. | | | H. m. s. | Sec. | μ | μ | km. |
|---|---|---|---|---|---|---|---|
| Feb. 24 | ..... | $eL_N$ | 23 02 25 | 8 | ..... | ..... | ..... |
| | | $eL_E$ | 23 03 50 | 7 | ..... | ..... | ..... |
| | | $M_E$ | 23 05 20 | 7 | 10 | ..... | ..... |
| | | $M_N$ | 23 06 50 | 6 | ..... | 30 | ..... |
| | | C | 23 07 .. | ..... | ..... | ..... | ..... |
| | | F | 23 17 .. | ..... | ..... | ..... | ..... |

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants.. E: V 10, $T_0$ 15; N: V 10, $T_0$ 16

| 1918. | | | H. m. s. | Sec. | μ | μ | km. |
|---|---|---|---|---|---|---|---|
| Feb. 12 | ..... | e | 20 22 .. | ..... | ..... | ..... | ..... |
| | | F | 20 30 .. | ..... | ..... | ..... | ..... |
| 13 | ..... | eL | 7 01 .. | 24 | ..... | ..... | ..... |
| | | L | 7 16 35 | 16 | ..... | ..... | ..... |
| | | F | 7 35 .. | ..... | ..... | ..... | ..... |

TABLE 2.—*Instrumental reports, February, 1918*—Continued.

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80 kg. vertical seismograph.

Instrumental constants.. $V$ 120 $T_0$ 26

| 1918. | | | *H. m. s.* | *Sec.* | μ | μ | *km.* | |
|---|---|---|---|---|---|---|---|---|
| Feb. 3 | ..... | $eL_E$... | 15 02 to | ..... | ..... | ..... | ..... | Heavy microseisms on NS. Amplitude of waves very small. |
| | ..... | ..... | 15 20 .. | 17 | ..... | ..... | ..... | |
| 4 | ..... | O..... | 20 39 ca | ..... | ..... | ..... | 3,100ca | |
| | | $eS_N$?.. | 20 50 06† | ..... | ..... | ..... | ..... | |
| | | i..... | 20 52 07 | 2 | ..... | ..... | ..... | Press report from Revelstoke. |
| | | eL.... | 20 53 30 | ..... | ..... | ..... | ..... | |
| | | L..... | 20 55 .. | 7 | ..... | ..... | ..... | |
| | | F..... | 21 .. .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | $eL_N$... | 1 41 54 | ..... | ..... | ..... | ..... | |
| | | $M_N$.... | 1 42 to | 18 | ..... | ..... | ..... | |
| | ..... | ..... | 1 46 .. | ..... | ..... | ..... | ..... | |
| | | $L_N$.... | 1 55 to | 10 | ..... | ..... | ..... | |
| | ..... | ..... | 1 58 .. | ..... | ..... | ..... | ..... | |
| | | F..... | 2 00 .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | e..... | 19 34 41 | 2.5 | ..... | ..... | ..... | |
| | | $eL_N$... | 19 35 06 | 12 | ..... | ..... | ..... | |
| | | F..... | 19 40 .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | $eL_N$... | 19 47 to | ..... | ..... | ..... | ..... | |
| | ..... | ..... | 19 50 .. | 10 | ..... | ..... | ..... | |
| 12 | ..... | $e_N$..... | 20 20 42 | 3 | ..... | ..... | ..... | |
| | | eL.... | 20 21 18 | 12 | ..... | ..... | ..... | |
| | | $M_N$.... | 20 22 .. | 12 | ..... | ..... | ..... | |
| | | F..... | 20 30 .. | ..... | ..... | ..... | ..... | |
| 13 | ..... | eL.... | 3 52 to | ..... | ..... | ..... | ..... | Δ of this quake appears to be of the same order as the next following quake. |
| | ..... | ..... | 4 05 .. | 20 | ..... | ..... | ..... | |
| 13 | ..... | O..... | 6 07 48 | ..... | ..... | ..... | 12,000 | |
| | | $P_E$?... | 6 22 24 | ..... | ..... | ..... | ..... | |
| | | $P_{rep}$... | 6 26 48 | ..... | ..... | ..... | ..... | Amoy, China. These readings are from the deformation instrument with a time scale of 17 mn. per hour. |
| | | $P_{rep}$.. | 6 29 42 | ..... | ..... | ..... | ..... | |
| | | S..... | 6 34 42 | ..... | ..... | ..... | ..... | |
| | | $S_{rep}$... | 6 42 42 | ..... | ..... | ..... | ..... | |
| | | $S_{rep}$... | 6 47 .. | ..... | ..... | ..... | ..... | |
| | | L..... | 7 00 24 | ..... | ..... | ..... | ..... | |
| | | $L_{rep}$... | 8 16 .. | ..... | ..... | ..... | ..... | |
| 13 | ..... | eL.... | 7 02 .. | 30 | ..... | ..... | ..... | These readings are from the record of the horizontal seismographs. The earlier phases are lacking on this instrument. Heavy microseisms. |
| | | L..... | 7 09 .. | 24 | ..... | ..... | ..... | |
| | | L..... | 7 14 .. | 16 | ..... | ..... | ..... | |
| | | L..... | 7 25 .. | 14 | ..... | ..... | ..... | |
| | | L..... | 7 35 .. | 14 | ..... | ..... | ..... | |
| | | F..... | 8 .. .. | ..... | ..... | ..... | ..... | |
| 18 | ..... | eL.... | 16 57 to | ..... | ..... | ..... | ..... | Very small amplitude. |
| | ..... | ..... | 17 04 .. | irreg. | ..... | ..... | ..... | |
| 19 | ..... | $L_E$.... | 17 22 to | 20 | ..... | ..... | ..... | |
| | ..... | ..... | 17 51 .. | 15 | ..... | ..... | ..... | |
| 20 | ..... | L..... | 6 54 to | ..... | ..... | ..... | ..... | |
| | ..... | ..... | 6 57 .. | 16 | ..... | ..... | ..... | |
| 23 | ..... | $eL_E$... | 19 02 .. | 20 | ..... | ..... | ..... | |
| | | $L_E$.... | 19 09 .. | 17 | ..... | ..... | ..... | |
| | | $L_E$.... | 19 13 .. | 16 | ..... | ..... | ..... | |
| | | $L_E$.... | 19 20 .. | 15 | ..... | ..... | ..... | |
| | | $L_E$.... | 19 27 .. | 15 | ..... | ..... | ..... | |
| | | F..... | 19 35 .. | ..... | ..... | ..... | ..... | |
| 24 | ..... | eL.... | 23 10 to | 17 | ..... | ..... | ..... | The shutter did not work while the record of this quake and the next following one were being made, and the time marks are missing. The amplitude of the waves for both quakes is very small. |
| | ..... | ..... | 23 30 ca | ..... | ..... | ..... | ..... | |
| 25 | ..... | eL.... | 7 ca .. | 17 | ..... | ..... | ..... | |
| | ..... | ..... | 7 30 ca | ..... | ..... | ..... | ..... | |
| 27 | ..... | $eL_E$... | 4 18 .. | 18 | ..... | ..... | ..... | |
| | | $L_E$.... | 4 26 .. | 16 | ..... | ..... | ..... | |
| | | F..... | 4 35 .. | ..... | ..... | ..... | ..... | |

† Time originally expressed in tenths of minutes.

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North. In the meridian.

Instrument constant.. $T_0$ 18. Pillar deviation: 1 mm. swing of boom=0.50″.

| 1918. | | | *H. m. s.* | *Sec.* | μ | μ | *km.* | |
|---|---|---|---|---|---|---|---|---|
| Feb. 3 | ..... | L..... | 14 58 48 | ..... | ..... | ..... | ..... | Marked gradual thickening. |
| | | eL.... | 15 00 54 | ..... | ..... | ..... | ..... | |
| | | M..... | 15 05 36 | ..... | *1,300 | ..... | ..... | |
| | | F..... | 15 31 .. | ..... | ..... | ..... | ..... | |
| 6 | ..... | L..... | 3 59 12 | ..... | ..... | ..... | ..... | |
| | | L..... | 4 00 30 | ..... | ..... | ..... | ..... | |
| | | eL.... | 4 09 30 | ..... | ..... | ..... | ..... | Gradual thickening. |
| | | M..... | 4 12 00 | ..... | *400 | ..... | ..... | |
| | | F..... | 4 33 .. | ..... | ..... | ..... | ..... | |
| 7 | ..... | L..... | 5 42 30 | ..... | ..... | ..... | ..... | Microseisms going on. F lost in microseisms. |
| | | eL.... | 5 58 48 | ..... | ..... | ..... | ..... | |
| | | M..... | 6 40 12 | ..... | *400 | ..... | ..... | |
| | | F..... | .. .. .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | L..... | 1 34 00 | ..... | ..... | ..... | ..... | F lost in microseisms. |
| | | L..... | 1 41 18 | ..... | ..... | ..... | ..... | |
| | | L..... | 1 52 06 | ..... | *100 | ..... | ..... | |
| | | L..... | 2 04 00 | ..... | ..... | ..... | ..... | |
| | | F..... | .. .. .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | L..... | 19 33 42 | ..... | *50 | ..... | ..... | |
| | | F..... | 19 40 36 | ..... | ..... | ..... | ..... | |
| 12 | ..... | iL.... | 20 20 42 | ..... | ..... | ..... | ..... | |
| | | M..... | 20 23 30 | ..... | *300 | ..... | ..... | |
| | | F..... | 20 29 36 | ..... | ..... | ..... | ..... | |
| 13 | ..... | L..... | 3 53 24 | ..... | ..... | ..... | ..... | |
| | | L..... | 4 00 00 | ..... | ..... | ..... | ..... | |
| | | M..... | 4 18 36 | ..... | *200 | ..... | ..... | |
| | | F..... | 4 24 30 | ..... | ..... | ..... | ..... | |
| 13 | ..... | eL.... | 6 44 54 | ..... | ..... | ..... | ..... | Markings at 6h 21m 12s and 6h 32m 36s, but may not be seismic. Amoy, China. |
| | | L..... | 7 00 06 | ..... | ..... | ..... | ..... | |
| | | iL..... | 7 08 18 | ..... | ..... | ..... | ..... | |
| | | eL.... | 7 11 18 | ..... | ..... | ..... | ..... | |
| | | M..... | 7 14 48 | ..... | *2,900 | ..... | ..... | |
| | | iL..... | 7 20 36 | ..... | ..... | ..... | ..... | |
| | | F..... | 8 52 24 | ..... | ..... | ..... | ..... | |
| 18 | ..... | L..... | 16 58 18 | ..... | *100 | ..... | ..... | |
| | | F..... | 17 06 36 | ..... | ..... | ..... | ..... | |
| 19 | ..... | L..... | 17 21 00 | ..... | ..... | ..... | ..... | Marked gradual thickening. |
| | | eL.... | 17 26 06 | ..... | ..... | ..... | ..... | |
| | | M..... | 17 30 12 | ..... | *800 | ..... | ..... | |
| | | F..... | 17 47 18 | ..... | ..... | ..... | ..... | |
| 20 | ..... | eL.... | 6 54 42 | ..... | ..... | ..... | ..... | Gradual thickening. |
| | | M..... | 6 56 12 | ..... | *300 | ..... | ..... | |
| | | F..... | 6 59 18 | ..... | ..... | ..... | ..... | |
| 23 | ..... | L..... | 19 02 42 | ..... | ..... | ..... | ..... | |
| | | M..... | 19 05 18 | ..... | *200 | ..... | ..... | |
| | | F..... | 19 14 36 | ..... | ..... | ..... | ..... | |
| 24 | ..... | L..... | 23 14 30 | ..... | ..... | ..... | ..... | |
| | | eL.... | 23 17 30 | ..... | ..... | ..... | ..... | |
| | | M..... | 23 20 30 | ..... | *300 | ..... | ..... | |
| | | L..... | 23 22 36 | ..... | ..... | ..... | ..... | |
| | | F..... | 23 34 18 | ..... | ..... | ..... | ..... | |
| 25 | ..... | eL.... | 7 03 12 | ..... | ..... | ..... | ..... | |
| | | M..... | 7 06 12 | ..... | *300 | ..... | ..... | Brief gradual thickening. |
| | | F..... | 7 15 12 | ..... | ..... | ..... | ..... | |
| 27 | ..... | L?..... | 4 16 30 | ..... | ..... | ..... | ..... | Thickenings barely perceptible. |
| | | L..... | 4 20 48 | ..... | *50 | ..... | ..... | |
| | | F..... | .. .. .. | ..... | ..... | ..... | ..... | |

* Trace amplitude.

TABLE 2.—*Instrumental reports, February, 1918*—Continued.

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Canada. *Victoria, B. C. Dominion Meteorological Service.* Lat., 48° 24′ N.; long., 123° 9′ W. Elevation, 67.7 meters. Subsoil: Rock. Instrument: Weichert, vertical; Milne horizontal pendulum, North. In the meridian. Instrumental constant.. $T_0$ 18. Pillar deviation: 1mm. swing of boom=0.54″. | | | | | | | | |
| 1918. | | | *H. m. s.* | *Sec.* | μ | μ | *km.* | |
| Feb. 3 | ..... | P..... | 14 45 36 | ..... | ..... | ..... | ..... | |
| | | L..... | 14 51 30 | ..... | ..... | ..... | ..... | |
| | | M..... | 14 55 26 | ..... | *400 | ..... | ..... | |
| | | F..... | 15 18 13 | ..... | ..... | ..... | ..... | |
| 4 | ..... | M..... | 20 40 16 | ..... | *50 | ..... | ..... | Near Revelstoke. |
| | | | VERTICAL. | | $A_z$ | | | |
| | | *P*..... | *20 39 46* | *3* | ..... | ..... | ..... | |
| | | *L*..... | *20 40 46* | *6* | ..... | ..... | ..... | |
| | | *M*..... | *20 40 52* | *6* | *16* | ..... | *550* | Near Revelstoke. |
| | | *F*..... | *20 43 28* | ..... | ..... | ..... | ..... | |
| 6 | ..... | L..... | 4 04 22 | ..... | *50 | ..... | ..... | |
| 7 | ..... | P..... | 5 35 22 | ..... | ..... | ..... | ..... | |
| | | L..... | 5 44 13 | ..... | ..... | ..... | ..... | |
| | | M..... | 5 47 49 | ..... | *500 | ..... | 4,200. | |
| | | F..... | 6 54 32 | ..... | ..... | ..... | ..... | |
| | | | VERTICAL. | | $A_z$ | | | |
| | | *M*..... | *6 06 00* | *30* | *2* | ..... | ..... | |
| 12 | ..... | L..... | 19 30 30 | ..... | *50 | ..... | ..... | |
| | | F..... | .. .. .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | P..... | 20 08 38 | ..... | ..... | ..... | ..... | |
| | | L..... | 20 12 34 | ..... | ..... | ..... | ..... | |
| | | M..... | 20 15 05 | ..... | $200 | ..... | ..... | |
| | | F..... | 20 21 31 | ..... | ..... | ..... | ..... | |
| 13 | ..... | L..... | 3 55 24 | ..... | *200 | ..... | ..... | Trace indistinct. |
| 13 | ..... | P..... | 6 31 10 | ..... | ..... | ..... | ..... | Trace rather indistinct. |
| | | S..... | 6 39 32 | ..... | ..... | ..... | ..... | |
| | | L..... | 6 46 36 | ..... | ..... | ..... | ..... | |
| | | M..... | 6 59 42 | ..... | *1,500 | ..... | 6,860 | |
| | | F..... | 8 10 02 | ..... | ..... | ..... | ..... | |
| | | | VERTICAL. | | $A_z$ | | | |
| | | *M*..... | *7 07 00* | ..... | *7* | ..... | ..... | |
| 13 | ..... | ..... | .. .. .. | ..... | ..... | ..... | ..... | Local tremor lasting about 1 second reported from several parts of the city at 13 hr. Not recorded. |
| 19 | ..... | L..... | 17 05 38 | ..... | ..... | ..... | ..... | Marked gradual thickening. |
| | | M..... | 17 14 38 | ..... | *400 | ..... | ..... | |
| | | F..... | 17 37 08 | ..... | ..... | ..... | ..... | |
| 27 | ..... | L..... | 4 07 07 | ..... | Below *50 | ..... | ..... | |

* Trace amplitude.

## SEISMOLOGICAL DISPATCHES.[1]

*Revelstoke, B. C., February 5, 1918.*

Several severe earthquakes were felt here yesterday, each shock lasting about 30 seconds. The movement was so marked that many persons experienced a feeling of nausea. No damage was caused so far as is known. (Associated Press.)

*Honolulu, Hawaii, February 16, 1918.*

The lava lake of Kilauea Volcano has taken a sudden rise and is at the highest level reached within the crater since 1894, according to reports reaching here to-day.

Lava spouting through cracks was gradually flowing over a depression in the rim and filling the valley caused by the last flow, the reports said.

Kilauea threatened to pour a stream over its sides on January 26, 1918. After a week of violent action it subsided and was calm until yesterday. (Associated Press.)

*Amoy, China, February 16, 1918.*

A severe earthquake here to-day destroyed many buildings and damaged scores of others. No fatalities have been reported as yet. (Associated Press.)

*Amoy, China, February 17, 1918.*

Earthquake shocks continued here last night and to-day. Many persons have been injured, and it is estimated that more than 100 houses have collapsed. Cable communication with Hongkong is interrupted. (Associated Press.)

*Amoy, China, February 20, 1918.*

Reports reaching here to-day from the districts visited by earthquake last Wednesday show some loss of life and heavy damage resulting. Two hundred deaths were reported from Swatow. The number of persons injured has not been tabulated.

One-fifth of the buildings, it was said, were destroyed and the remainder damaged. Great damage was reported from Chongchowfu and delta towns, exact details of which were lacking. (Associated Press.)

*San Salvador, Republic of Salvador, February 25, 1918.*

Telegraphic communication with the interior of Guatemala is interrupted as a result of earthquake shocks of an extremely violent character. (Associated Press.)

*Amoy, China, February 25, 1918.*

Nearly 10,000 persons lost their lives as a result of recent earthquakes in the Amoy hinterland, according to the latest reports from Swatow. A series of earthquakes on February 16 and 17 caused extensive damage over a considerable area of Kwangtung. Buildings were wrecked in Amoy and many other towns. Several villages in the Amoy hinterland were virtually destroyed. (Associated Press.)

[1] Reported by the organizations indicated and collected by the seismological station at Georgetown University, Washington, D. C.

# SECTION VI.—BIBLIOGRAPHY.

## RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

**American climatological and clinical association.**
Transactions for the year 1917. Volume 33. Philadelphia. 1917. xxxiv, 212 p., l. illus. plates. (incl. ports.) 24½ cm.

**Bemmelen, W[illem] van.**
The semi-diurnal horizontal oscillation of the free atmosphere up to 10 km. above sea level deduced from pilot balloon observations at Batavia, by W. Van Bemmelen and J. Boerema. cover-title, 17 p. incl. tables. fold. chart. 26½ cm. At head of title: K. Akademie van wetenschappen te Amsterdam. (Reprinted from Proceedings, vol. 20, no. 1. p. [119]-135.) Dated May 26, 1917.

**Blue Hill observatory.**
[Report of the director, 1916-1917.] (Excerpted from Official register of Harvard university, vol. 15, no. 6. Feb. 28, 1918. p. 224-228. Reports of the president and the treasurer of Harvard college, 1917-18.) 23½ cm.

**Fiji. Department of agriculture.**
Annual report for the year 1916. Suva, Fiji. 1917. 37 p. tables. 33½ cm. At head of title: Legislative council, Fiji. Council paper, no. 107. M. P. 272/17. [Meteorology, p. 32-35.]

**Gautier, Raoul.**
La neige à Genève (1857-1917) et revue de quelques hivers à neige spécialement de l'hiver 1784-1785. Genève. 1917. cover-title. tables. 23 cm. (Extrait des Archives des sciences physiques et naturelles. Quatrième période, t. 43. Mai, 1917. p.[361]-383.)

**Geneva. Observatoire.**
Observations météorologiques faites aux fortifications de Saint-Maurice pendant l'année 1916. Résumé par Raoul Gautier et Ernest Rod. Genève. 1917. 57 p., l. incl. tables. 22½ cm. (Extrait des Archives des sciences physiques et naturelles, juin et août 1916, janvier, mars et octobre 1917.)

Résumé météorologique de l'année 1916 pour Genève et le Grand Saint-Bernard par Raoul Gautier. Genève. 1917. 104 p. incl. tables. 22½ cm. (Tiré des Archives des sciences de la bibliothèque universelle, août et septembre 1917.)

**Gil, Pedro Gimeno.**
Pluviometría de la región Austro-oriental, primavera, verano y otoño de 1916. Valencia. 1917. p.l., 79 p. incl. tables. charts. 24½ cm. At head of title: Anales del Instituto general y técnico de Valencia.

**Great Britain. Meteorological Office.**
Twelfth annual report of the meteorological committee ... for the year ended 31st March, 1917 ... London. 1917. 16 p. 24½ cm.

**Groot, Cornelis J. de.**
On the matter and elimination of strays. An investigation under the auspices of the Dutch East Indian department of telegraphs. charts, diagrs., map. 24 cm. (Excerpted from the Wireless, Lond. v. 5. nos. 54-58. Sept. 1917-Jan. 1918. p. [374]-379; [450]-455; [520]-525; [632]-638; [700]-706.) Reprinted ... from the proceedings of the institute of radio engineers.

**Guppy, H. B.**
Plants, seeds, and currents in the West Indies and Azores; the results of investigations carried out in those regions between 1906 and 1914. London. 1917. xi, 531 p. front. tables, maps (part, fold.) 24 cm. [Currents of the Atlantic, p. 46-83.]

**Hankow. Griffith John College.**
Meteorological survey for 1917 comp. from readings taken by the 1st Hankow troop of Chinese boy scouts. Hankow. 1918. cover-title. charts. 16½ x 21½ cm.

**Hepworth, M[elville] W[illis] Campbell.**
The relation between pressure, temperature, and air circulation over the South Atlantic Ocean. Notes with reference to a set of monthly wind charts of the South Atlantic Ocean which were prepared in the meteorological office and were originally published by the hydrographic department of the Admiralty, in January, 1904; 2d ed. London. 1917. 14 p. charts. 24½ cm. M. O. 177 (1917).

**Mellish, Henry.**
Weather of 1917, at Hodsock Priory, Worksop. 7 p. table. chart. 22 cm.

**Miami Conservancy District.**
Report of the chief engineer, Arthur E. Morgan, submitting a plan for the protection of the district from flood damage. Dayton, Ohio. 1916. 3 v. in 1. tables (part. fold.). charts (part. fold.). fold. maps. 23 cm.

**Mill, Hugh Robert.**
Map of the British Isles. Annual rainfall and isobars ... Average annual rainfall, by H. R. Mill. London. [1917] col. map. 98½ x 76 cm. "The isobars are copied from the Monthly weather reports."

**Murphy, John Allen.**
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**Padua Dias, Antonio de.**
Meteorologia e climatologia, com applicações á agricultura. S. Paulo. 1917. 1-[241] iv p. illus. plate. charts. tables. 23 cm. [Obras consultadas, p. [241] O clima do Brasil, p. [165]-[240.]

**Philippine Islands. Weather Bureau.**
Instrucciones prácticas y breves nociones de meteorología para los observadores del Weather bureau, por el P. M. Saderra Masó ... 2 ed. Manila. 1917. 103 p. illus. plates. diagrs. 25½ cm.

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**Tondorf, F. A.**
Registration of earthquakes and press dispatches on earthquakes from January 1, 1917 to January 1, 1918. Washington. 1918. cover-title. 30 p., incl. tables. 23 cm. (Georgetown university publication. Bulletin of the Seismographic station, no. 22, p. 1-30. Jan. 1, 1918.) Fourteenth series, no. 4.

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Climate, considered especially in relation to man. Second ed. rev. New York, London. 1918. xv, 380 p., incl. tables. charts. 21½ cm.

**Wells, A. E.**
Results of recent investigations of the smelter smoke problem. 19 p. 6 charts. 23½ cm. (Reprinted from the Journal of industrial and engineering chemistry. vol. 9, no. 8, p. 640. July, 1917.)

**West, Frank L.**
Orchard heating, by F. L. West and N. E. Edlefsen. Logan, Utah. 1917. 48 p. illus. tables. 23 cm. (Utah agricultural college experiment station. Bulletin no. 161.) References, p. 47-48.

**Woodward, K. W.**
Tree growth and climate in the United States. (Excerpted from Journal of forestry, published by the Society of American foresters, Washington, v. 15, May, 1917, p. 521-531.) 23 cm.

## RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

*Aerial Age. New York. v. 6. March 4, 1918.*

**Duffield, W. G.** Meteorology: thunderstorms. p. 1118–1119.

*Aerial Age. New York. v. 7. March 25, 1918.*

**Duffield, W. C.** Meteorology: air currents and eddies. p. 115.

*Aeronautical journal. London. v. 22. January, 1918.*

**Dines, Wi[lliam] H[enry].** Meteorology in relation to aeronautics. p. 17–29; 33–35.

*Engineering news-record. New York. v. 80. 1918.*

**Harrison, J. L.** First frost is never responsible for cracked concrete roadways. p. 418–420. (Feb. 28.)

**Ice gorges** on Mississippi river sink many vessels. p. 526–527. (Mar. 14.)

*Franklin institute. Journal. Philadelphia. v. 185. March, 1918.*

**Humphreys, W[illiam] J[ackson].** Physics of the air. p. 359–372. (Continuation.)

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**La morto de Dro Judzi Wada.** p. 9.

**Nakamura, Saemontaro.** On the time curve of the earthquake waves for near earthquake. p. 10–18.

*Popular astronomy. Northfield. v. 26. March, 1918.*

**Todd, David.** On selecting stations for totality of 1918, July 8. and probable cloud conditions at eclipse time. p. 166–183. [Detailed discussion of probable cloudiness at various stations.]

*Royal meteorological society. Quarterly journal. London. v. 44. January, 1918.*

**Simpson, G[eorge] C.** The twelve-hourly barometer oscillation. p. 1–19.

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**Bryant, Walter W[illiam].** Abnormal temperature, with special reference to the daily maximum air temperature at Greenwich. p. 23–30.

**Bolton, P.** Computation of wind velocity from pilot balloon observations. p. 31–40.

**Bilham, E[rnest] G[eorge].** The use of monthly mean values in climatological analysis. p. 41–48. [Abstract in this REVIEW.]

**Brooks, C[harles] E.** The meteorology of Ocean Island during the period 1905–1916. p. 50–53.

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*Science. New York. v. 47. March 15, 1918.*

**Marvin, C[harles] F.** The nomenclature of thermometric scales. p. 267–268. [Reprint from this REVIEW.]

*Scientific American supplement. New York. v. 85. March 9, 1918.*

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*Académie des sciences. Comptes rendus. Paris. Tome 166. 1918.*

**Brazier, E. C.** Sur la variation de la vitesse du vent en altitude. p. 176–177. (28 jan.)

**Dunoyer, L.** Sur la variation diurne du vent et sur l'influence de la répartition des mers de nuages. p. 293–295. (18 fév.)

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*Archives des science physiques et naturelles. Genève. v. 45. Janvier, 1918.*

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**Mercanton, P[aul] L[ouis].** Le bruit de la canonnade du 21 janvier 1917. p. 146–148.

*Géographie. Paris. Tome 31. no. 5. 1917.*

**Rabot, Charles.** L'hiver de 1917 en Norvège et en Suède. p. 343–349.

**Rabot, Charles.** Les avalanches dans les Alpes suisses en 1917. p. 358–361.

# SECTION VII.—WEATHER AND DATA FOR THE MONTH.

## THE WEATHER OF FEBRUARY, 1918.

P. C. DAY, Climatologist and Chief of Division.

[Dated: Climatological Division, Weather Bureau, Apr. 1, 1918.]

### PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds for February, 1918, are graphically shown on Chart VII, while the means at the several stations, with the departures from the normal, are shown in Tables I and III.

The month opened with pressure above the normal throughout all interior portions of the country, and for the greater part of the first decade the pressure continued high in the central districts west of the Rocky Mountains. During the second decade pressure was generally lower than normal in the above-mentioned district and as a rule moderately low in the interior and northern districts to the eastward. The third decade of the month was marked by a general decrease in pressure over most northern districts, in fact the barometer readings were moderately low over the entire country, but with the highest readings over the southern districts.

For the month as a whole the barometric pressure averaged above normal throughout the South generally from the Atlantic to the Pacific, extending in the east as far North as the Ohio River and the Middle Atlantic States, while it was below the seasonal average over nearly all other districts. The positive departures were generally not large, but in portions of the Lakes region, Canada, and the far Northwest the negative departures were considerable.

This distribution of the more permanent centers of high and low pressure favored warm southerly winds over the greater part of the country from the Plains region eastward, the northern limits of these winds extending to the Canadian boundary, from the Lakes region eastward. Southerly winds prevailed to a considerable extent also in the districts to westward of the Rocky Mountains.

### TEMPERATURE.

February, unlike the two months that preceded it, was generally free from prolonged periods of cold, but there were frequent changes from one extreme to the other, particularly during the early part of the month. Low temperature prevailed at the beginning of the month in the upper Lakes Region, the upper Mississippi Valley, and from Nebraska to Texas, but with seasonal temperature near the east Gulf coast and in northern Montana. Higher temperatures rapidly overspread the Central Valleys, the Lake region, and to eastward and continued for a few days when a marked cold wave moved into the upper Mississippi Valley and thence eastward, giving decidedly low temperature in the northeastern States and part of the Lakes Region about the 5th, several stations recording the coldest February weather for more than a decade. Toward the end of the first week, moderate weather overspread most sections and continued until about the middle of the second week when somewhat colder weather obtained generally for a few days; however the period as a whole averaged warmer than normal over practically the whole country with an excess of from 15 to 20 degrees daily in the middle Mississippi Valley and the middle and northern Plains States. Early in the third week a cold wave prevailed in most northern districts, and the temperature was decidedly low in the Great Plains and Plateau States, and after a few days of somewhat higher temperature cold weather again overspread the region from the Plains to the North Atlantic States. The third week averaged warmer than normal in the Gulf and South Atlantic States, about normal in the North Atlantic States and south of the Ohio River elsewhere it was below the seasonal average, the middle and northern Plains States averaging from 20 to nearly 30 degrees colder than normal. The temperature during the last week of the month was normal or slightly below in the middle and northern Plateau and North Pacific States, but elsewhere it was higher than normal, the warmth being most pronounced in the middle and northern Plains States, the Lakes Region, Central Valleys, and the Southwest.

For the month as a whole the temperature was above the normal in the Central Valleys and Southern States, slightly below in parts of the Plateau and Pacific Coast States, and considerably below in the upper Lakes region and extreme northeast. The lowest temperature reported at a regular Weather Bureau station during the month was 36 degrees below zero at Havre, Mont., and the temperature reached freezing or below in most districts during the early part of the month.

### PRECIPITATION.

Frequent rains occurred in the North Pacific Coast States throughout the first week of the month and light precipitation fell in the eastern section of the country during the early part of this period, but elsewhere generally fair weather prevailed. During the first few days of the second week moderate precipitation occurred in the Ohio Valley, Lakes Region, and northern and middle Atlantic States, and about three days later rather heavy rain fell in portions of Missouri, Illinois, and the Lakes region, and again during the latter part of the week and for several succeeding days snows, often heavy, prevailed in most northern districts. Shortly after the middle of the month liberal rains set in over southern California, where they were sorely needed, and continued intermittently during the remainder of the month in much of California, Arizona, and the adjoining States. Toward the end of the third week precipitation prevailed over most of the eastern half of the country, with rather large falls in parts of Tennessee, the Ohio Valley, and the northeastern States. During the last week of the month rather heavy precipitation occurred in the Lakes region and northeastern States, and the month closed with some rain or snow over a considerable area from the lower Lakes to the Southern Rocky Mountain region.

The precipitation for the month as a whole was moderately large over nearly all parts of the Pacific coast, and

the amounts were near normal in the Lakes Region and to the southward also in portions of the west Gulf States and locally in Kansas, Colorado, and Arizona. In other districts as a rule the precipitation was light, particularly in eastern Virginia, the greater part of Florida, and generally in the States between the Mississippi River and the Rocky Mountains.

The snowfall for the month as a whole was generally not large, and there was a gradual decrease in the depth of the snow cover in most sections. However, from time to time there was considerable snow in some of the higher portions of the far western mountains, particularly in California, but the stored snow supply at the end of the month was almost everywhere less than the average at that date, and in the southern districts especially the prospects for late melting were unfavorable.

Except for the rather deep snow covering in some portions of the eastern coal-mining districts during the early part of the month which somewhat hampered operations, the weather conditions were generally not unfavorable for mining and transportation.

### RELATIVE HUMIDITY.

The relative humidity for the month as a whole was below the normal in the central Plains States and in the Rocky Mountain region and to the westward. Elsewhere there was relatively more moisture in the atmosphere than usually prevails in February, due largely to the prevalence of moist winds blowing inland from the Gulf of Mexico and Atlantic Ocean.

### GENERAL SUMMARY.

The moderate weather, especially during the latter part of the month, was favorable for farm work and the development of vegetation. Plowing for cotton and corn progressed satisfactorily and some planting was done in the extreme south. The weather of the month was favorable for winter grains, except that it was too dry over parts of the Great Plains and there was some freezing and thawing from Ohio eastward to the middle Atlantic coast. In Nebraska the condition of winter wheat improved during February, and in Kansas the drought was relieved in the north and east during the last few days of the month. There was little progress in the advancement of the crop in Oklahoma, and likewise it made slow growth and the stand was poor in Texas. In the central Mississippi and lower Ohio Valley States, the wheat plants were small, but they seemed to be well rooted and presented a satisfactory appearance. Winter wheat was in an unusually excellent condition in the north Pacific Coast States, and generally the mild weather was favorable to winter grains, except where there was a decided lack of moisture in the soil. There was considerable damage to oats during the winter in the Southeastern States.

The planting of crops progressed favorably in the extreme South and early truck made good growth in Florida. Ranges were in good condition in some southern portions of the Rocky Mountain system and over the Pacific States and the month was generally favorable for stock. Early fruits progressed favorably in the South, although some damage was done to citrus fruit in the lower Mississippi Valley by cold weather, and peach buds appeared to be badly winterkilled in the Central States, and more or less damaged in the Lakes Region.

*Average accumulated departures for February, 1918.*

| Districts. | Temperature. | | | Precipitation. | | | Cloudiness. | | Relative humidity. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | General mean for the current month. | Departure for the current month. | Accumulated departure since Jan. 1. | General mean for the current month. | Departure for the current month. | Accumulated departure since Jan. 1. | General mean for the current month. | Departure from the normal. | General mean for the current month. | Departure from the normal. |
| | °F. | °F. | °F. | Ins. | Ins. | Ins. | 0–10. | | P. ct. | |
| New England | 22.4 | −3.4 | −10.8 | 2.47 | −0.90 | −1.70 | 6.1 | +0.7 | 77 | +3 |
| Middle Atlantic | 33.3 | +0.5 | −8.4 | 1.32 | −2.00 | −1.30 | 5.5 | 0.0 | 71 | −2 |
| South Atlantic | 52.4 | +4.6 | −2.0 | 1.41 | −2.70 | −3.70 | 5.0 | −0.2 | 76 | +1 |
| Florida Peninsula | 70.6 | +3.8 | +1.1 | 0.90 | −1.60 | −2.70 | 4.0 | −0.2 | 81 | +1 |
| East Gulf | 56.3 | +5.4 | −0.7 | 2.15 | −2.60 | −1.30 | 6.0 | +0.5 | 76 | +1 |
| West Gulf | 52.6 | +3.0 | −4.4 | 0.98 | −1.80 | −3.00 | 5.8 | +0.9 | 74 | 0 |
| Ohio Valley and Tennessee | 38.0 | +2.4 | −9.7 | 2.25 | −1.30 | −0.60 | 6.1 | −0.1 | 75 | 0 |
| Lower Lakes | 24.5 | −0.2 | −10.6 | 2.25 | −0.20 | 0.00 | 6.6 | −0.2 | 80 | 0 |
| Upper Lakes | 17.0 | −2.2 | −12.0 | 2.06 | +0.30 | +0.90 | 6.1 | −0.2 | 83 | +2 |
| North Dakota | 11.5 | +4.6 | −0.6 | 0.20 | −0.30 | −0.30 | 4.9 | −0.1 | 83 | +2 |
| Upper Mississippi Valley | 26.7 | +2.2 | −8.6 | 1.19 | −0.60 | −0.90 | 5.3 | 0.0 | 78 | −1 |
| Missouri Valley | 28.2 | +3.8 | −4.7 | 0.94 | 0.00 | 0.00 | 4.4 | −0.8 | 75 | −1 |
| Northern slope | 23.1 | +1.6 | −1.3 | 0.73 | −0.10 | +0.20 | 5.4 | +0.2 | 70 | −3 |
| Middle slope | 37.2 | +5.0 | −2.8 | 0.79 | 0.00 | +0.10 | 3.7 | −0.8 | 57 | −10 |
| Southern slope | 49.5 | +5.0 | +0.2 | 0.11 | −0.80 | −1.80 | 3.6 | −0.9 | 45 | −17 |
| Southern Plateau | 45.8 | +1.0 | +0.3 | 0.50 | −0.20 | −0.10 | 3.1 | −0.5 | 45 | −3 |
| Middle Plateau | 32.4 | −0.5 | +1.0 | 0.94 | −0.20 | −0.20 | 5.1 | −0.1 | 61 | −6 |
| Northern Plateau | 33.6 | +1.5 | +5.8 | 0.92 | −0.50 | +0.10 | 6.9 | +0.5 | 69 | −6 |
| North Pacific | 41.4 | +0.1 | +4.8 | 6.88 | +1.60 | +0.80 | 7.2 | 0.0 | 78 | −4 |
| Middle Pacific | 48.3 | −0.7 | +1.2 | 4.39 | +0.10 | −3.50 | 5.1 | −0.5 | 74 | −3 |
| South Pacific | 53.6 | +1.0 | +2.7 | 5.47 | +3.00 | +1.00 | 5.0 | +0.6 | 69 | −2 |

## WEATHER CONDITIONS OVER THE NORTH ATLANTIC OCEAN DURING FEBRUARY, 1917.

The data presented are for February, 1917, and comparison and study of same should be in connection with those appearing in the REVIEW for that month.

Chart IX (XLVI–18) shows for February, 1917, the principal storm track and averages of pressure, air temperature, water surface temperature, and prevailing direction of the wind at 7 a. m., 75th meridian time (Greenwich mean noon). Notes on the locations and courses of the more severe storms of the month are included in the following general summary.

### PRESSURE.

The distribution of the mean atmospheric pressure for the month did not differ materially from the normal. The Azores, or North Atlantic HIGH, was nearly normal in position and extent, and slightly below in intensity. Separated by a shallow trough there was a second long and narrow area of high pressure that extended from the 48th parallel to eastern Texas. St. Johns, N. F., was near the southern limits of a well-developed LOW, with a minimum average pressure of 29.65 inches, where the normal is about 29.82 inches. The gradients over the western and middle divisions of the ocean were practically normal, while east of the 30th meridian they were comparatively weak. The pressure changes from day to day were not unusual for February when the fluctuations are often rapid, especially in northern waters.

The following table gives for a number of selected 5-degree squares the average pressure for each of the three decades, as well as the highest and lowest individual readings reported during the month within the respective squares.

*Pressure over North Atlantic during February, 1917, by 5-degree squares.*

| Position of 5-degree squares. | | Decade means. | | | Extremes. | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Highest. | | Lowest. | |
| Latitude. | Longitude. | I. | II. | III.* | Pressure. | Date. | Pressure. | Date. |
| ° | ° | *In.* | *In.* | *In.* | *In.* | | *In.* | |
| 60–65 N. | 20–25 W. | 29.86 | 29.86 | 29.90 | 30.10 | Feb. 7,8,10 | 29.48 | Feb. 3. |
| 55–60 N. | 35–40 W. | 29.77 | 29.69 | 29.86 | 30.35 | Feb. 10 | 29.18 | Feb. 2,17. |
| 55–60 N. | 0– 5 W. | 30.07 | 30.10 | 30.09 | 30.48 | Feb. 8 | 29.62 | Feb. 3. |
| 50–55 N. | 55–60 W. | 29.50 | 29.78 | 29.89 | 30.10 | Feb. 23 | 29.02 | Feb. 3. |
| 50–55 N. | 25–30 W. | 29.92 | 29.69 | 29.99 | 30.40 | Feb. 7 | 29.50 | Feb. 2. |
| 50–55 N. | 5–10 W. | 30.13 | 30.00 | 30.25 | 30.52 | Feb. 8 | 29.66 | Feb. 1. |
| 45–50 N. | 65–70 W. | 29.51 | 29.96 | 30.05 | 30.30 | Feb. 19 | 29.30 | Feb. 4. |
| 45–50 N. | 50–55 W. | 29.44 | 29.75 | 29.80 | 30.36 | Feb. 26 | 28.80 | Feb. 1,3. |
| 45–50 N. | 0– 5 W. | 30.00 | 29.98 | 30.29 | 30.40 | Feb. 26,27 | 29.68 | Feb. 1. |
| 40–45 N. | 70–75 W. | 29.64 | 30.06 | 30.10 | 30.42 | Feb. 12,13 | 29.04 | Feb. 5. |
| 40–45 N. | 5–10 W. | 29.85 | 29.93 | 30.31 | 30.40 | Feb. 26 | 29.59 | Feb. 13. |
| 35–40 N. | 75–80 W. | 29.93 | 30.14 | 30.13 | 30.60 | Feb. 13 | 29.40 | Feb. 9. |
| 35–40 N. | 35–40 W. | 30.14 | 29.98 | 30.10 | 30.41 | Feb. 6 | 29.70 | Feb. 18. |
| 35–40 N. | 10–15 W. | 29.90 | 29.98 | 30.24 | 30.32 | Feb. 20,22 | 29.55 | Feb. 4. |
| 30–35 N. | 25–30 W. | 30.16 | 30.14 | 30.21 | 30.40 | Feb. 6 | 29.82 | Feb. 13. |
| 30–35 N. | 5–10 W. | 29.88 | 30.06 | 30.18 | 30.34 | Feb. 19 | 29.50 | Feb. 4. |
| 25–30 N. | 95–100 W. | 30.29 | 30.06 | 30.00 | 30.82 | Feb. 2 | 29.83 | Feb. 17. |
| 25–30 N. | 15–20 W. | 30.07 | 30.15 | 30.17 | 30.33 | Feb. 19 | 29.74 | Feb. 12. |
| 20–25 N. | 85–90 W. | 30.17 | 30.08 | 30.08 | 30.43 | Feb. 3 | 29.98 | Feb. 17. |
| 15–20 N. | 20–25 W. | 30.06 | 30.07 | 30.06 | 30.20 | Feb. 16,17 | 29.92 | Feb. 12. |

* Mean of last 8 days of the month.

The means presented in the above table are based on the daily pressure values, determined by interpolation, of each square on the MS. daily synoptic chart of the North Atlantic Ocean compiled by the Marine Section of the Weather Bureau.

## GALES.

The number of days on which gales occurred during February, 1917, was considerably less than usual over the entire ocean, with the exception of the limited area between the 25th and 40th parallels and the 70th and 75th meridians, where they were slightly above the normal.

On February 1 a LOW was central about 150 miles east of St. Johns, N. F., where the barometer reading was 28.80 inches. Westerly and southwesterly gales of from 40 to 70 miles an hour, accompanied by hail and snow, prevailed over the region between the 35th and 45th parallels and the 35th and 55th meridians. This area of low pressure remained nearly stationery until February 4, but the storm area varied considerably from day to day, reaching its maximum extent on the 3d, when there was a HIGH with a crest of 30.64 inches near Pensacola, Fla. The steep gradient between these two areas was responsible for the strong northwest gales that swept the American coast from the Gulf of Mexico to Nova Scotia; heavy winds were also reported as far east as the 45th meridian, north of the 38th parallel. On the 5th a LOW of 29.04 inches was central near Boston, while the HIGH with a crest of 30.58 inches was in the vicinity of Corpus Christi, Tex. Gales of increased force raged along the coast, velocities of over 50 miles an hour being reported by a number of vessels, although the storm area was not so extensive as on the 4th. On the 5th there was a second LOW near latitude 50°, longitude 25°, causing moderate to strong gales over the eastern division of the steamer lanes.

On the 6th the American LOW surrounded the greater part of Newfoundland, the isotherm of 29.1 inches extending well into the Gulf of St. Lawrence. Winds of gale force were still reported by a few vessels between the 30th and 45th parallels, although they had moderated considerably over the storm area of the day before. The European LOW of the 5th was now central near Balboa, Spain, and moderate northwest gales were encountered by a few vessels between the 20th meridian and the French coast. From the 7th to the 9th, inclusive, a LOW of moderate intensity was central near the Straits of Gibralter, and on the former date northerly gales prevailed between the Madeiras and the Azores. On the 9th a well-developed disturbance was in the vicinity of New York, where the barometer read 29.36 inches; light to moderate winds prevailed along the greater part of the American coast, and gales were encountered some distance to the eastward of Georgia, one vessel near latitiude 37°, longitude 61°, recording a southerly wind of 55 miles an hour. This LOW moved in a northeasterly direction, increasing in intensity, and on the 10th covered a large portion of the Gulf of St. Lawrence, the barometer at Chatham reading 28.94 inches. Westerly and southwesterly gales, with snow, swept over the territory between the 35th and 41st parallels and the 60th meridian and the American coast. From the 11th to the 15th the atmospheric conditions were comparatively sluggish, and no heavy winds were reported, although there were a few areas of low pressure of slight intensity over different parts of the ocean during that period. On Chart III (XLV–12) tracks of low areas for February, 1917, a LOW is shown that on the evening of the 12th was near the boundary of Arizona and California. This was too far south and west to appear on Chart IX until the evening of the 13th, when it is shown as LOW *I*, near El Paso, Tex. It moved eastward with a comparatively uniform rate, and on the morning of the 16th the center was about 200 miles east of Boston. The maximum velocity of the wind reported was 40 miles an hour, experienced by three vessels in widely scattered positions in the southerly and easterly gradients. LOW *I* then moved rapidly toward the northeast, and on the morning of the 17th was off the coast of Labrador, conditions of wind and weather having changed but little since the previous day. It curved sharply toward the southeast, and on the 18th the center was near latitude 38°, longitude 35°; moderate winds still prevailed, for the most part, although a few reports were received denoting moderate gales, from vessels as far south as the Azores. It then curved sharply toward the northeast, and on the 19th was apparently central near latitude 53°, longitude 29°, although this was indeterminate on account of lack of observations. The force of the wind had moderated since the previous day, as the maximum velocity reported over the steamer lanes was 36 miles an hour. The LOW recurved toward the east, and on the 20th surrounded the greater part of Ireland; wind conditions apparently remained about the same as on the 19th, although no vessels reports were received from east of the 20th meridian. From the 20th to the 23d no atmospheric depression of any consequence was reported. On the 24th a well-developed LOW of 29.50 inches was central near latitude 40°, longitude 43°; one vessel in the southwest quadrant encountered a northwest gale of 65 miles an hour, although the storm area was limited. For the remainder of the month there were no unusual features, and only a few scattered reports showing winds of gale force were received during that period.

## AIR TEMPERATURES.

The average monthly temperature of the air over the ocean, as compared with the normal, varied considerably in different localities. Large positive departures oc-

curred in the waters adjacent to the coasts of Europe and the United States, while over a limited area off the coast of Newfoundland the temperature was considerably below the normal. In the northern part of the Gulf of Mexico, the departures ranged from +1 to +6 degrees, while the southern portion they were slightly negative.

The average temperature for the three decades of the month did not differ as much in northern waters, as in January, and the fluctuations from day to day also seemed to be less than usual. In the 5-degree square that includes the coast of Labrador, where the greatest daily variations usually occur, the temperature ranged from 15° on the 13th to 36° on the 8th, and again on the 19th.

The following table gives the temperature departures for the month at a number of Canadian and United States Weather Bureau Stations on the Atlantic and Gulf coasts.

| | °F. | | °F. |
|---|---|---|---|
| St. Johns, N. F. | −0.6 | Norfolk, Va. | −3.0 |
| Sydney, C. B. I. | −0.6 | Hatteras, N. C. | −2.6 |
| Halifax, N. S. | −0.8 | Charleston, S. C. | −0.9 |
| Eastport, Me. | −3.8 | Key West, Fla. | −1.6 |
| Portland, Me. | −4.5 | Tampa, Fla. | +0.8 |
| Boston, Mass. | −2.2 | Mobile, Ala. | +1.2 |
| Nantucket, Mass. | −5.0 | New Orleans, La. | +2.5 |
| Block Island, R. I. | −3.8 | Galveston, Tex. | +1.6 |
| New York, N. Y. | −2.9 | Corpus Christi, Tex. | +3.1 |

### WATER SURFACE TEMPERATURE.

The monthly average temperature of the water at the surface was considerably below the normal over the entire ocean with the exception of the region in the vicinity of the Azores and the Madeiras, and within the northeast trade wind limits, where the positive departures ranged from 1 to 3 degrees. The temperature of the Gulf Stream was from 1 to 3 degrees below the normal, while the negative departures in the waters adjacent to the American coast, north of Florida, were even greater. The variations in the temperature, from day to day, in the waters off the Banks of Newfoundland, were not unusually large for that region, the temperature varying from 35° on the 20th to 50° on the 14th.

### FOG.

The month was remarkable for the scarcity of fog over all parts of the ocean. The maximum amount occurred in the 5-degree square between latitude 40°–45°, longitude 50°–55°, where it was reported on two days, a percentage of 7, while the normal percentage for that square is from 30 to 35. Fog was observed on one day off Hatteras, and also in the Gulf of Mexico, while none was recorded over the steamer lanes east of the Banks of Newfoundland.

### HAIL AND SNOW.

There was little hail reported during the month as it did not occur on more than one day in any 5-degree square.

Snow was recorded on six days in the square between latitude 40°–45°, and longitude 60°–65°, and on from two to four days in the waters adjacent to the American coast, north of the 35th parallel. It was scarce over the steamer routes, none being reported east of the 40th meridian.

*Winds of 50 miles per hour (22.4 m./sec.) or over, during February, 1918.*

| Station. | Date. | Velocity. | Direction. | Station. | Date. | Velocity. | Direction. | Station. | Date. | Velocity. | Direction. | Station. | Date. | Velocity. | Direction. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Mis./hr.* | | | | *Mis./hr.* | | | | *Mis./hr.* | | | | *Mis./hr.* | |
| Alpena, Mich. | 25 | 54 | nw. | Ellendale, N. Dak. | 14 | 57 | ne. | Mount Tamalpais- | | | | Providence, R. I. | 4 | 54 | nw. |
| Do. | 26 | 54 | nw. | El Paso, Tex. | 11 | 50 | w. | Continued. | | | | Do. | 5 | 53 | nw. |
| Block Island, R. I. | 5 | 70 | nw. | Do. | 27 | 66 | sw. | Do. | 24 | 64 | nw. | Do. | 15 | 59 | nw. |
| Do. | 15 | 58 | nw. | Erie, Pa. | 8 | 50 | se. | Do. | 27 | 58 | n. | Do. | 20 | 65 | nw. |
| Do. | 21 | 50 | nw. | Do. | 12 | 56 | sw. | Nantucket, Mass. | 19 | 55 | sw. | Do. | 26 | 68 | w. |
| Do. | 26 | 68 | w. | Do. | 14 | 50 | se. | Do. | 20 | 56 | sw. | Rochester, N. Y. | 26 | 50 | w. |
| Buffalo, N. Y. | 3 | 52 | w. | Do. | 15 | 50 | sw. | Do. | 26 | 55 | w. | Saginaw, Mich. | 25 | 54 | nw. |
| Do. | 10 | 50 | w. | Do. | 19 | 50 | se. | Nashville, Tenn. | 25 | 60 | nw. | Do. | 26 | 52 | nw. |
| Do. | 12 | 70 | sw. | Eureka, Cal. | 6 | 50 | sw. | New York, N. Y. | 4 | 58 | nw. | St. Louis, Mo. | 14 | 65 | sw. |
| Do. | 14 | 60 | sw. | Evansville, Ind. | 12 | 54 | sw. | Do. | 5 | 56 | nw. | Do. | 19 | 50 | nw. |
| Do. | 15 | 70 | sw. | Do. | 25 | 55 | w. | Do. | 12 | 50 | w. | Do. | 25 | 50 | nw. |
| Do. | 19 | 72 | w. | Grand Junct'n, Cal. | 13 | 52 | w. | Do. | 13 | 50 | w. | Sandusky, Ohio. | 12 | 50 | sw. |
| Do. | 20 | 64 | w. | Green Bay, Wis. | 14 | 57 | ne. | Do. | 15 | 66 | nw. | Do. | 14 | 52 | w. |
| Do. | 24 | 54 | w. | Hannibal, Mo. | 14 | 54 | sw. | Do. | 17 | 60 | nw. | Do. | 25 | 58 | w. |
| Do. | 25 | 64 | s. | Indianapolis, Ind. | 14 | 50 | w. | Do. | 20 | 70 | nw. | Do. | 26 | 54 | nw. |
| Do. | 26 | 84 | w. | Do. | 19 | 54 | w. | Do. | 21 | 62 | nw. | Sandy Hook, N. J. | 5 | 52 | w. |
| Burlington, Vt. | 19 | 56 | s. | Do. | 25 | 71 | s. | Do. | 26 | 81 | nw. | Do. | 19 | 52 | s. |
| Canton, N. Y. | 26 | 62 | w. | Iola, Kans. | 27 | 58 | ne. | Norfolk, Va. | 26 | 58 | w. | Do. | 20 | 53 | sw. |
| Chattanooga, Tenn. | 25 | 53 | nw. | Kansas City, Mo. | 25 | 53 | nw. | North Head, Wash. | 3 | 58 | se. | Do. | 26 | 73 | w. |
| Cheyenne, Wyo. | 2 | 59 | nw. | Knoxville, Tenn. | 25 | 30 | s. | Do. | 4 | 72 | se. | Sioux City, Iowa. | 25 | 51 | nw. |
| Do. | 3 | 53 | w. | Lander, Wyo. | 5 | 56 | w. | Do. | 6 | 60 | se. | Syracuse, N. Y. | 9 | 50 | s. |
| Do. | 5 | 76 | w. | Lexington, Ky. | 12 | 60 | sw. | Do. | 8 | 52 | se. | Do. | 14 | 51 | s. |
| Do. | 6 | 53 | w. | Do. | 14 | 56 | sw. | Do. | 9 | 58 | se. | Do. | 19 | 52 | s. |
| Do. | 14 | 64 | w. | Do. | 25 | 56 | nw. | Do. | 11 | 50 | sw. | Do. | 26 | 56 | w. |
| Do. | 25 | 62 | w. | Lincoln, Nebr. | 14 | 54 | nw. | Do. | 25 | 50 | sw. | Tatoosh Island, | | | |
| Do. | 26 | 71 | w. | Little Rock, Ark. | 25 | 51 | nw. | Do. | 26 | 56 | nw. | Wash. | 3 | 64 | s. |
| Cincinnati, Ohio. | 12 | 51 | sw. | Louisville, Ky. | 12 | 60 | sw. | Oswego, N. Y. | 26 | 50 | w. | Do. | 4 | 68 | s. |
| Cleveland, Ohio. | 15 | 50 | w. | Do. | 14 | 55 | s. | Pierre, S. Dak. | 13 | 50 | ne. | Do. | 8 | 64 | s. |
| Do. | 19 | 52 | w. | Do. | 25 | 65 | w. | Do. | 14 | 52 | ne. | Do. | 9 | 60 | s. |
| Do. | 20 | 54 | w. | Memphis, Tenn. | 25 | 60 | nw. | Pittsburgh, Pa. | 26 | 56 | w. | Do. | 15 | 53 | e. |
| Do. | 25 | 56 | w. | Minneapolis, Minn. | 14 | 54 | ne. | Point Reyes Light, | | | | Do. | 19 | 52 | e. |
| Do. | 26 | 66 | w. | Modena, Utah. | 13 | 60 | sw. | Cal. | 6 | 54 | s. | Do. | 25 | 60 | s. |
| Columbus, Ohio. | 14 | 52 | w. | Mount Tamalpais, | | | | Do. | 7 | 60 | nw. | Toledo, Ohio. | 15 | 54 | sw. |
| Do. | 15 | 54 | w. | Cal. | 5 | 70 | sw. | Do. | 14 | 58 | nw. | Do. | 19 | 50 | s. |
| Do. | 19 | 52 | nw. | Do. | 6 | 58 | s. | Do. | 16 | 58 | s. | Do. | 25 | 62 | w. |
| Do. | 25 | 64 | nw. | Do. | 7 | 60 | nw. | Do. | 17 | 71 | nw. | Do. | 26 | 54 | w. |
| Do. | 26 | 58 | nw. | Do. | 11 | 64 | nw. | Do. | 18 | 62 | nw. | Trenton, N. J. | 20 | 56 | sw. |
| Corpus Christi, Tex | 27 | 54 | se. | Do. | 12 | 76 | nw. | Do. | 23 | 50 | s. | Do. | 26 | 70 | w. |
| Dayton, Ohio. | 25 | 60 | nw. | Do. | 14 | 54 | nw. | Do. | 24 | 61 | nw. | Washington, D. C. | 26 | 50 | nw. |
| Detroit, Mich. | 14 | 54 | w. | Do. | 16 | 50 | s. | Do. | 26 | 62 | nw. | Wichita, Kans. | 14 | 59 | nw. |
| Do. | 26 | 58 | nw. | Do. | 17 | 54 | nw. | Port Huron, Mich. | 25 | 57 | nw. | Do. | 27 | 52 | ne. |
| Duluth, Minn. | 25 | 50 | nw. | Do. | 18 | 64 | nw. | Do. | 26 | 55 | w. | | | | |

## CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

*Condensed climatological summary of temperature and precipitation by sections, February, 1918.*

| Section. | Temperature. | | | | | | | | Precipitation. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Section average. | Departure from the normal. | Monthly extremes. | | | | | | Section average. | Departure from the normal. | Greatest monthly. | | Least monthly. | |
| | | | Station. | Highest. | Date. | Station. | Lowest. | Date. | | | Station. | Amount. | Station. | Amount. |
| | °F. | °F. | | °F. | | | °F. | | In. | In. | | In. | | In. |
| Alabama | 53.6 | +6.6 | 3 stations | 86 | 25† | Valley Head | 9 | 5 | 2.39 | −3.23 | Spring Hill | 3.72 | Tallassee | 1.38 |
| Arizona | 47.4 | +0.9 | Yuma date orchard | 87 | 6 | Fort Valley | −13 | 1 | 1.18 | −0.13 | Williams | 5.08 | 2 stations | T. |
| Arkansas | 46.9 | +5.1 | Pine Bluff | 93 | 27 | Bentonville | 4 | 1 | 1.17 | 2.43 | Rison | 4.44 | Murfreesboro | 0.00 |
| California | 46.9 | −1.6 | Calexico | 88 | 6 | Madeline | −18 | 15 | 6.18 | +1.77 | Branscomb | 19.04 | Bagdad | 0 |
| Colorado | 28.6 | +2.2 | Hochne | 80 | 7 | 2 stations | −36 | 1 | 1.26 | +0.23 | Cumbres | 4.57 | Rocky Ford | T. |
| Florida | 65.8 | +6.2 | Brooksville (1) | 92 | 28 | Bristol | 25 | 5 | 0.81 | −2.80 | Bonifay | 3.55 | 2 stations | 0.00 |
| Georgia | 54.1 | +6.7 | Glennville | 90 | 28 | 2 stations | 10 | 5 | 2.22 | −2.84 | Blakely | 6.48 | St. George | 0.31 |
| Hawaii (for January) | 69.2 | +0.9 | Mahukona | 93 | 24 | Waimea | 43 | 22 | 10.22 | +3.26 | Honomu | 36.73 | Lahaina | 2.23 |
| Idaho | 27.6 | −0.3 | Payette | 69 | 5 | Blackfoot Dam | −38 | 1 | 1.77 | −0.12 | Burke | 6.74 | Hotspring | T. |
| Illinois | 31.1 | +3.7 | Equality | 80 | 28 | Morrison | −24 | 1 | 1.56 | −0.69 | Casey | 2.84 | Equality | 0.36 |
| Indiana | 31.2 | +2.1 | Rome | 79 | 28 | 2 stations | −22 | 5 | 1.88 | −1.00 | Crown Point | 4.91 | Elliston | 0.48 |
| Iowa | 23.0 | +2.5 | Clarinda | 70 | 23 | Washta | −36 | 4 | 0.95 | −0.20 | Olin | 2.10 | Algona | 0.09 |
| Kansas | 35.9 | +5.0 | Medicine Lodge | 87 | 23 | Blakeman | −22 | 1 | 0.79 | −0.44 | Natoma | 3.11 | Medora | 0.00 |
| Kentucky | 39.3 | +3.7 | Bowling Green | 83 | 28 | Anhcorage | − 8 | 5 | 2.04 | −1.56 | Edmonton | 4.57 | Cherokee Park | 0.47 |
| Louisiana | 58.9 | +6.4 | Minden | 92 | 25 | 2 stations | 20 | 3 | 2.28 | −2.52 | Franklin | 3.89 | Shreveport | 0.16 |
| Maryland-Delaware | 33.5 | +0.1 | Millsboro, Del | 71 | 28 | Grantsville, Md | −15 | 5 | 1.51 | −1.71 | Oakland, Md | 5.14 | Solomons, Md | 0.58 |
| Michigan | 17.7 | −1.3 | St. Joseph | 60 | 41 | Houghton Lake | −48 | 1 | 1.95 | +0.18 | Hastings | 4.66 | Eagle Harbor | 0.23 |
| Minnesota | 13.4 | +2.7 | Lynd | 59 | 11 | Warroad | −41 | 4 | 0.42 | −0.24 | Caledonia | 2.35 | Glencoe | T. |
| Mississippi | 53.8 | +5.6 | Yazoo | 91 | 25 | Hernando | 17 | 1 | 2.47 | −2.54 | Holly Bluff | 4.44 | Stoneville | 1.10 |
| Missouri | 34.9 | +4.6 | Doniphan | 83 | 24 | Bethany | −25 | 1 | 1.11 | −1.26 | Liberty | 2.15 | Dean | 0.00 |
| Montana | 20.8 | −0.5 | Crow Agency | 65 | 7 | Chinook | −50 | 20 | 0.65 | −0.10 | Heron | 5.00 | Big Ox | 0 |
| Nebraska | 27.6 | +3.1 | 3 stations | 80 | 23 | Weeping Water | −29 | 1 | 0.71 | −0.01 | Hayes Center | 2.00 | 2 stations | 0.15 |
| Nevada | 33.2 | −0.5 | Las Vegas | 79 | 14 | Potts | −16 | 24 | 1.30 | +0.29 | Marlette Lake | 9.01 | Sulphur | 0.08 |
| New England | 29.0 | −1.0 | Woodbine | 67 | 28 | 2 stations | −23 | 2† | 2.08 | −1.78 | Dover | 3.41 | Asbury Park | 1.03 |
| New Jersey | 18.8 | −3.2 | Waterbury, Conn | 62 | 25† | Van Buren, Me | −40 | 22 | 2.72 | −0.57 | Somerset, Vt | 5.33 | Enosburg Falls, Vt | 1.33 |
| New Mexico | 39.6 | +2.0 | Pearl | 88 | 23 | Dulce | −19 | 3 | 0.62 | −0.18 | Anchor Mine | 4.08 | 5 stations | 0.00 |
| New York | 21.2 | −0.4 | Fredonia | 60 | 90 | Adams Centre | −35 | 5 | 2.55 | −0.15 | North Lake | 5.72 | Hemlock | 0.75 |
| North Carolina | 46.6 | +5.6 | Hot Springs | 83 | 25 | Banners Elk | 1 | 5 | 1.57 | −2.68 | Murphy | 5.50 | Altapass | 0.16 |
| North Dakota | 10.8 | +2.9 | Taylor | 60 | 24 | Beach | −41 | 20 | 0.20 | −0.29 | Bierman | 0.64 | 2 stations | 0.00 |
| Ohio | 31.0 | +3.4 | 2 stations | 78 | 28 | 4 stations | −24 | 5 | 2.16 | −0.52 | Montpelier | 4.82 | Put-in-Bay | 0.64 |
| Oklahoma | 43.5 | +4.4 | Arapaho | 99 | 24 | .....do | − 5 | 1 | 0.36 | −0.88 | Jefferson | 2.36 | Whiteagle | 0.0 |
| Oregon | 38.0 | 0 | Pilot Rock | 71 | 9 | Crescent | −14 | 14 | 4.35 | −0.48 | Deadwood | 19.96 | Harriman | 0.13 |
| Pennsylvania | 28.2 | +1.1 | Uniontown | 69 | 29 | Saegerstown | −34 | 5 | 2.46 | −0.57 | Somerset | 4.82 | Lawrenceville | 0.55 |
| Porto Rico | 73.6 | +0.3 | San German | 92 | 1 | Jayuya | 52 | 10 | 3.92 | +1.24 | Corozal | 9.07 | Hac Destino | 0.25 |
| South Carolina | 52.4 | +5.4 | Florence (1) | 88 | 15 | Anderson | 11 | 5 | 1.89 | −2.46 | Liberty | 3.55 | Darlington | 0.80 |
| South Dakota | 19.4 | +2.7 | Spearfish | 74 | 10 | Camp Crook | −37 | 20 | 0.58 | −0.05 | Kadoka | 2.40 | Ellingson | T. |
| Tennessee | 45.2 | +5.5 | Bolivar | 83 | 28 | Erasmus | 1 | 5 | 2.24 | −2.18 | Copperhill | 4.11 | Covington | 0.74 |
| Texas | 53.6 | +3.6 | Fowlerton | 101 | 27 | Dalhart | − 3 | 1 | 1.03 | −0.89 | Hempstead | 6.50 | 11 stations | 0.00 |
| Utah | 29.5 | −2.2 | Lemay | 78 | 16† | Blacks Fork | −27 | 16 | 1.09 | −0.38 | Silver Lake | 7.31 | Victor | 0.00 |
| Virginia | 39.5 | +3.7 | Roanoke | 83 | 28 | Woodstock | −10 | 25 | 0.81 | −2.41 | Elk Knob | 2.61 | Culpeper | 0.10 |
| Washington | 33.9 | −0.6 | Granger | 70 | 5 | 3 stations | −14 | 20† | 4.30 | +0.72 | Yale | 17.80 | Winthrop | 0.25 |
| West Virginia | 35.4 | +3.7 | Green Sulphur Spgs | 81 | 28 | Smithfield | −19 | 5 | 3.12 | −0.05 | Pickens | 6.60 | Wardensville | 0.45 |
| Wisconsin | 15.9 | +0.4 | Beloit (2) | 56 | 24 | Hatfield | −51 | 1 | 1.11 | −0.03 | Beloit | 2.55 | Grantsburg | 0.13 |
| Wyoming | 21.8 | 0 | 2 stations | 67 | 10† | Soda Butte | −50 | 19 | 0.88 | +0.05 | Sand Lake | 4.69 | Hyattsville | 0.00 |
| LATE REPORT—JANUARY, 1918. | | | | | | | | | | | | | | |
| Nebraska | 14.5 | −6.9 | Nenzel | 69 | 3 | Purdum | −31 | 11 | 0.74 | +0.16 | West Point | 2.19 | Chadron | 0.18 |

† Other dates also.

## DESCRIPTION OF TABLES AND CHARTS.

(See the REVIEW for January, 1918, p. 48.)

TABLE I.—*Climatological data for Weather Bureau stations, February, 1918.*

| Districts and stations. | Elevation of instruments. | | | Pressure. | | | Temperature of the air. | | | | | | | | | | Mean wet thermometer. | Mean temperature of the dew point. | Mean relative humidity. | Precipitation. | | | Wind. | | | | | Clear days. | Partly cloudy days. | Cloudy days. | Average cloudiness, tenths. | Total snowfall. | Snow on ground at end of month. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barometer above sealevel. | Thermometer above ground. | Anemometer above ground. | Station, reduced to mean of 24 hours. | Sealevel, reduced to mean of 24 hours. | Departure from normal. | Mean max.+mean min.÷2. | Departure from normal. | Maximum. | Date. | Mean maximum. | Minimum. | Date. | Mean minimum. | Greatest daily range. | | | | | Total. | Departure from normal. | Days with 0.01 inch or more. | Total movement. | Prevailing direction. | Maximum velocity. Miles per hour. | Maximum velocity. Direction. | Maximum velocity. Date. | | | | | | |
| | *Ft.* | *Ft.* | *Ft.* | *In.* | *In.* | *In.* | °*F.* | °*F.* | °*F* | | °*F* | °*F.* | | °*F* | °*F.* | | °*F.* | °*F.* | % | *In.* | *In.* | | *Miles.* | | | | | | | *0–10* | *In.* | *In.* |
| ***New England.*** | | | | | | | **22.4** | **−3.4** | | | | | | | | | | | **77** | **2.47** | **−0.9** | | | | | | | | | **6.1** | | |
| Eastport | 76 | 67 | 85 | 29.88 | 29.97 | −0.01 | 17.6 | −3.8 | 49 | 26 | 27 | −16 | 6 | 8 | 38 | | 17 | 12 | 78 | 3.95 | +0.3 | 14 | 9,301 | w. | 49 | se. | 26 | 8 | 9 | 11 | 6.2 | 24.0 | 4.3 |
| Greenville, Me | 1,070 | 6 | .... | 28.72 | 29.95 | ..... | 10.2 | ..... | 49 | 25 | 22 | −29 | 5 | −2 | 41 | | ..... | ..... | ..... | 2.47 | ..... | 12 | ..... | ..... | ..... | ..... | ..... | 7 | 7 | 14 | .... | 16.4 | 34.0 |
| Portland, Me | 103 | 82 | 117 | 29.89 | 30.02 | .00 | 18.8 | −5.0 | 53 | 15 | 28 | −14 | 5 | 10 | 41 | | 17 | 12 | 75 | 2.62 | −1.0 | 15 | 6,193 | nw. | 46 | se. | 26 | 7 | 10 | 11 | 6.0 | 16.0 | 2.9 |
| Concord | 288 | 70 | 79 | 29.69 | 30.02 | −.02 | 17.4 | −6.2 | 52 | 26 | 30 | −16 | 5 | 5 | 43 | | ..... | ..... | ..... | 1.82 | +1.5 | 12 | 3,845 | n. | 45 | w. | 26 | 11 | 9 | 8 | 5.4 | 14.8 | 7.7 |
| Burlington | 404 | 11 | 48 | 29.54 | 30.01 | −.02 | 15.2 | −2.7 | 47 | 20 | 25 | −23 | 5 | 5 | 50 | | ..... | ..... | ..... | 1.79 | −0.4 | 16 | 10,807 | s. | 56 | s. | 19 | 5 | 7 | 16 | 7.5 | 9.4 | 7.4 |
| Northfield | 876 | 12 | 60 | 29.02 | 30.01 | −.03 | 13.8 | −3.4 | 57 | 20 | 28 | −24 | 5 | 0 | 59 | | 12 | 9 | 82 | 2.05 | −0.2 | 13 | 6,161 | s. | 48 | se. | 26 | 4 | 5 | 19 | 7.9 | 9.4 | 13.6 |
| Boston | 125 | 115 | 188 | 29.88 | 30.03 | −.01 | 26.9 | −1.1 | 57 | 15 | 37 | −10 | 5 | 17 | 43 | | 24 | 19 | 74 | 2.30 | −1.1 | 12 | 8,221 | sw. | 48 | w. | 26 | 6 | 13 | 9 | 5.5 | 5.7 | 0.1 |
| Nantucket | 12 | 14 | 90 | 30.03 | 30.04 | .00 | 27.7 | −4.9 | 52 | 25 | 35 | −6 | 5 | 20 | 34 | | 26 | 23 | 80 | 2.22 | −0.9 | 9 | 12,586 | sw. | 56 | sw. | 20 | 5 | 9 | 14 | 6.7 | 3.1 | 0.0 |
| Block Island | 26 | 11 | 46 | 30.02 | 30.05 | −.01 | 27.0 | −4.2 | 49 | 25 | 34 | −6 | 5 | 20 | 32 | | 25 | 22 | 81 | 2.09 | −2.2 | 11 | 14,557 | nw. | 70 | nw. | 5 | 9 | 6 | 13 | 6.2 | 1.8 | 0.0 |
| Narragansett Pier | .... | 9 | .... | ..... | ..... | ..... | 25.9 | −2.4 | 54 | 15 | 36 | −10 | 5 | 16 | 38 | | ..... | ..... | ..... | 3.96 | ..... | 10 | ..... | w. | ..... | ..... | ..... | 15 | 6 | 7 | .... | 6.1 | 0.0 |
| Providence | 160 | 215 | 251 | 29.86 | 30.04 | −.01 | 26.0 | −3.0 | 55 | 15 | 36 | −10 | 5 | 16 | 40 | | 24 | 21 | 82 | 2.87 | −1.6 | 15 | 11,032 | nw. | 68 | w. | 26 | 9 | 8 | 11 | 5.6 | 4.8 | 0.0 |
| Hartford | 159 | 122 | 140 | 29.88 | 30.07 | +.01 | 25.2 | −2.0 | 56 | 25 | 35 | −11 | 5 | 16 | 41 | | 22 | 16 | 70 | 2.43 | −1.1 | 12 | 6,439 | s. | 41 | w. | 26 | 14 | 6 | 8 | 4.5 | 5.8 | T. |
| New Haven | 106 | 117 | 155 | 29.95 | 30.08 | +.01 | 26.8 | −1.5 | 55 | 15 | 36 | −7 | 5 | 18 | 39 | | 24 | 19 | 74 | 3.04 | −0.7 | 11 | 6,804 | s. | 41 | w. | 26 | 6 | 13 | 9 | 5.5 | 4.1 | 0.0 |
| ***Middle Atlantic States.*** | | | | | | | **33.3** | **+0.5** | | | | | | | | | | | **71** | **1.32** | **−2.0** | | | | | | | | | **5.5** | | |
| Albany | 97 | 102 | 115 | 29.95 | 30.06 | −0.01 | 22.0 | −1.6 | 52 | 13 | 32 | −15 | 5 | 12 | 42 | | 20 | 15 | 75 | 1.35 | −1.2 | 11 | 6,106 | s. | 48 | s. | 19 | 10 | 5 | 13 | 5.7 | 3.2 | T. |
| Binghamton | 871 | 10 | 69 | 29.09 | 30.05 | −.03 | 24.2 | −0.5 | 54 | 19 | 33 | −17 | 2 | 13 | 48 | | ..... | ..... | ..... | 1.60 | −0.3 | 13 | 5,073 | nw. | 36 | sw. | 26 | 4 | 11 | 13 | 6.8 | 1.4 | T. |
| New York | 314 | 414 | 454 | 29.73 | 30.09 | +.01 | 29.6 | −1.1 | 58 | 20 | 38 | −7 | 5 | 21 | 41 | | 26 | 18 | 62 | 1.98 | −1.8 | 9 | 14,555 | nw. | 81 | w. | 26 | 5 | 13 | 10 | 5.9 | 3.5 | 0.0 |
| Harrisburg | 374 | 94 | 104 | 29.70 | 30.12 | +.03 | 29.6 | −0.3 | 56 | 25 | 38 | −5 | 5 | 21 | 35 | | 26 | 20 | 69 | 2.12 | −0.6 | 9 | 5,063 | nw. | 44 | nw. | 26 | 8 | 7 | 13 | 5.6 | 2.0 | T. |
| Philadelphia | 117 | 123 | 190 | 29.98 | 30.12 | +.02 | 33.4 | +0.6 | 61 | 25 | 42 | −2 | 5 | 25 | 35 | | 30 | 25 | 74 | 1.57 | −1.8 | 7 | 6,841 | nw. | 36 | nw. | 26 | 8 | 9 | 11 | 5.7 | 2.5 | 0.0 |
| Reading | 325 | 81 | 98 | 29.75 | 30.12 | ..... | ..... | ..... | 59 | 25 | 39 | −6 | 5 | 20 | 39 | | 26 | 20 | 70 | 2.64 | −0.9 | 8 | 5,423 | nw. | 39 | nw. | 26 | 9 | 6 | 13 | 6.2 | 2.5 | T. |
| Scranton | 805 | 111 | 119 | 29.19 | 30.09 | +.01 | 26.8 | −0.1 | 62 | 12 | 37 | −10 | 5 | 16 | 45 | | 23 | 19 | 77 | 1.26 | −1.5 | 9 | 6,009 | sw. | 44 | w. | 26 | 5 | 12 | 11 | 6.5 | 2.5 | 0.0 |
| Atlantic City | 52 | 37 | 48 | 30.06 | 30.12 | +.01 | 31.7 | −1.3 | 62 | 15 | 39 | −4 | 5 | 24 | 31 | | 29 | 25 | 78 | 1.34 | −1.9 | 9 | 5,826 | nw. | 35 | nw. | 26 | 11 | 8 | 9 | 5.0 | 1.8 | 0.0 |
| Cape May | 18 | 13 | 49 | 30.13 | 30.16 | +.05 | 32.4 | −1.7 | 60 | 15 | 40 | 0 | 5 | 25 | 34 | | ..... | ..... | ..... | 1.17 | −2.1 | 8 | 6,365 | s. | 42 | nw. | 26 | 12 | 6 | 10 | .... | 1.6 | 0.0 |
| Sandy Hook | 22 | 10 | 57 | 30.07 | 30.09 | ..... | 29.4 | ..... | 56 | 20 | 37 | −4 | 5 | 22 | 36 | | 27 | 22 | 74 | 1.73 | ..... | 10 | 12,271 | nw. | 73 | w. | 26 | 9 | 11 | 8 | 4.8 | 2.1 | 0.0 |
| Trenton | 190 | 159 | 183 | 29.88 | 30.09 | ..... | 30.0 | ..... | 60 | 25 | 39 | −6 | 5 | 21 | 38 | | 27 | 22 | 75 | 1.84 | −1.4 | 9 | 8,868 | sw. | 70 | w. | 26 | 11 | 5 | 12 | 5.6 | 1.9 | 0.0 |
| Baltimore | 123 | 100 | 113 | 29.99 | 30.13 | +.02 | 35.4 | +0.8 | 61 | 15 | 44 | 0 | 5 | 26 | 35 | | 30 | 23 | 63 | 1.04 | −2.5 | 7 | 4,643 | s. | 31 | sw. | 26 | 12 | 6 | 10 | 5.0 | 2.4 | 0.0 |
| Washington | 112 | 62 | 85 | 30.00 | 30.13 | +.02 | 36.8 | +2.3 | 69 | 28 | 47 | −2 | 5 | 27 | 36 | | 41 | 24 | 66 | 0.83 | −2.6 | 8 | 5,263 | nw. | 50 | nw. | 26 | 12 | 7 | 9 | 4.8 | 1.5 | 0.0 |
| Lynchburg | 681 | 153 | 188 | 29.37 | 30.13 | +.02 | 41.2 | +3.0 | 80 | 28 | 52 | 6 | 5 | 30 | 44 | | 35 | 30 | 67 | 0.53 | −3.0 | 6 | 5,253 | w. | 47 | nw. | 26 | 14 | 5 | 9 | 5.2 | 1.3 | 0.0 |
| Norfolk | 91 | 170 | 205 | 30.06 | 30.16 | +.05 | 43.7 | +1.9 | 75 | 15 | 53 | 8 | 5 | 34 | 35 | | 39 | 33 | 71 | 0.26 | −3.5 | 4 | 9,969 | ne. | 58 | w. | 26 | 15 | 5 | 8 | 4.4 | 1.0 | 0.0 |
| Richmond | 144 | 11 | 52 | 29.98 | 30.14 | +.03 | 41.2 | +1.3 | 76 | 28 | 52 | 3 | 5 | 30 | 36 | | 35 | 30 | 70 | 0.91 | −2.2 | 8 | 6,487 | sw. | 42 | sw. | 26 | 11 | 7 | 10 | 5.4 | 1.3 | 0.0 |
| Wytheville | 2,203 | 49 | 55 | 27.70 | 30.15 | +.03 | 38.4 | +3.3 | 73 | 28 | 49 | 5 | 5 | 28 | 39 | | 33 | 29 | 74 | 0.68 | −3.4 | 12 | 5,553 | w. | 40 | w. | 26 | 12 | 4 | 12 | 5.1 | 0.1 | 0.0 |
| ***South Atlantic States.*** | | | | | | | **52.4** | **+4.6** | | | | | | | | | | | **76** | **1.41** | **−2.7** | | | | | | | | | **5.0** | | |
| Asheville | 2,255 | 70 | 84 | 27.76 | 30.17 | +0.04 | 44.4 | +5.9 | 77 | 28 | 56 | 9 | 5 | 32 | 42 | | 37 | 30 | 67 | 1.98 | −2.7 | 9 | 6,944 | se. | 36 | nw. | 26 | 8 | 12 | 8 | 5.0 | 0.2 | 0.0 |
| Charlotte | 773 | 153 | 161 | 29.30 | 30.15 | +.03 | 48.6 | +4.5 | 75 | 28 | 58 | 21 | 5 | 40 | 28 | | 42 | 37 | 71 | 1.92 | −2.5 | 9 | 7,432 | sw. | 48 | w. | 26 | 10 | 7 | 11 | 5.6 | T. | 0.0 |
| Hatteras | 11 | 12 | 50 | 30.14 | 30.15 | +.04 | 46.2 | −0.4 | 70 | 28 | 53 | 20 | 5 | 40 | 31 | | 42 | 39 | 82 | 1.73 | −2.8 | 9 | 10,243 | sw. | 40 | sw. | 26 | 9 | 11 | 8 | 5.1 | T. | 0.0 |
| Manteo | 12 | 4 | 46 | ..... | ..... | ..... | 47.0 | ..... | 72 | 13 | 56 | 20 | 5 | 38 | ..... | | ..... | ..... | ..... | 0.48 | −3.9 | 4 | ..... | sw. | ..... | ..... | ..... | 15 | 5 | 8 | .... | 0.0 | 0.0 |
| Raleigh | 376 | 103 | 110 | 29.74 | 30.15 | +.04 | 48.0 | +4.7 | 77 | 28 | 59 | 15 | 5 | 37 | 32 | | 42 | 37 | 73 | 1.16 | −3.2 | 11 | 5,855 | sw. | 35 | nw. | 26 | 12 | 3 | 13 | 5.0 | T. | 0.0 |
| Wilmington | 78 | 81 | 91 | 30.08 | 30.17 | +.05 | 51.6 | +3.9 | 77 | 15 | 61 | 24 | 5 | 42 | 37 | | 45 | 42 | 80 | 2.77 | −0.6 | 10 | 5,629 | sw. | 31 | sw. | 25 | 11 | 11 | 6 | 4.4 | 0.0 | 0.0 |
| Charleston | 48 | 11 | 92 | 30.12 | 30.17 | +.05 | 55.2 | +3.5 | 78 | 20 | 64 | 27 | 5 | 47 | 30 | | 49 | 46 | 82 | 1.31 | −2.1 | 6 | 6,981 | sw. | 31 | sw. | 25 | 14 | 7 | 7 | 4.1 | 0.0 | 0.0 |
| Columbia, S. C | 351 | 41 | 57 | 29.78 | 30.17 | +.06 | 53.8 | +6.0 | 81 | 28 | 64 | 25 | 5 | 44 | 33 | | 46 | 40 | 68 | 1.42 | −3.2 | 9 | 5,287 | w. | 38 | sw. | 26 | 9 | 9 | 10 | 5.3 | 0.0 | 0.0 |
| Greenville, S. C | 1,039 | 113 | 122 | 29.02 | 30.13 | ..... | 49.4 | ..... | 74 | 28 | 59 | 17 | 5 | 40 | 31 | | 43 | 38 | 73 | 2.99 | ..... | 11 | 6,026 | sw. | 45 | nw. | 26 | 7 | 14 | 7 | 5.3 | T. | 0.0 |
| Augusta | 180 | 62 | 77 | 29.96 | 30.16 | +.04 | 54.4 | +5.4 | 82 | 28 | 65 | 25 | 5 | 44 | 38 | | 49 | 45 | 78 | 1.82 | −2.6 | 8 | 3,847 | nw. | 34 | n. | 16 | 9 | 8 | 11 | 5.4 | 0.0 | 0.0 |
| Savannah | 65 | 150 | 194 | 30.10 | 30.17 | +.05 | 59.0 | +6.5 | 80 | 16 | 68 | 29 | 5 | 49 | 35 | | 51 | 47 | 77 | 0.66 | −2.6 | 7 | 7,815 | sw. | 36 | nw. | 4 | 11 | 6 | 11 | 5.3 | 0.0 | 0.0 |
| Jacksonville | 43 | 200 | 245 | 30.13 | 30.18 | +.06 | 62.8 | +5.9 | 83 | 20 | 71 | 34 | 5 | 54 | 27 | | 56 | 52 | 79 | 0.21 | −3.2 | 5 | 8,301 | sw. | 39 | sw. | 26 | 9 | 12 | 7 | 4.8 | 0.0 | 0.0 |
| ***Florida Peninsula.*** | | | | | | | **70.6** | **+3.8** | | | | | | | | | | | **81** | **0.90** | **−1.6** | | | | | | | | | **4.0** | | |
| Key West | 22 | 10 | 64 | 30.10 | 30.12 | +0.05 | 73.1 | +2.3 | 81 | 3 | 78 | 55 | 5 | 68 | 17 | | 67 | 65 | 82 | 0.12 | −1.5 | 3 | 6,764 | e. | 26 | n. | 4 | 21 | 7 | 0 | 1.7 | 0.0 | 0.0 |
| Miami | 25 | 71 | 79 | 30.14 | 30.16 | ..... | 70.4 | +1.6 | 80 | 26 | 76 | 45 | 5 | 65 | 20 | | 66 | 63 | 80 | 2.51 | −0.2 | 8 | 5,839 | e. | 22 | n. | 5 | 13 | 11 | 4 | 4.1 | 0.0 | 0.0 |
| Sand Key | 23 | 39 | 72 | 30.08 | 30.11 | +0.4 | 72.2 | ..... | 79 | 26 | 74 | 56 | 5 | 70 | 12 | | 68 | 66 | 82 | 0.07 | ..... | 2 | 9,581 | e. | 40 | ne. | 5 | 22 | 5 | 1 | 2.2 | 0.0 | 0.0 |
| Tampa | 35 | 79 | 92 | 30.14 | 30.18 | +.08 | 68.4 | +7.5 | 85 | 28 | 77 | 42 | 5 | 59 | 30 | | 60 | 57 | 79 | 0.08 | −3.2 | 4 | 4,263 | nw. | 22 | sw. | 12 | 10 | 17 | 1 | 4.1 | 0.0 | 0.0 |
| ***East Gulf States.*** | | | | | | | **56.3** | **+5.4** | | | | | | | | | | | **76** | **2.15** | **−2.6** | | | | | | | | | **6.0** | | |
| Atlanta | 1,174 | 190 | 216 | 28.91 | 30.17 | +0.05 | 50.8 | +5.6 | 76 | 28 | 60 | 16 | 5 | 41 | 35 | | 44 | 38 | 68 | 1.82 | −2.8 | 11 | 8,209 | nw. | 48 | nw. | 26 | 11 | 4 | 13 | 5.6 | 0.0 | 0.0 |
| Macon | 370 | 78 | 87 | 29.78 | 30.18 | +.06 | 54.1 | +5.2 | 82 | 28 | 65 | 23 | 5 | 44 | 40 | | 47 | 42 | 70 | 2.30 | −2.3 | 7 | 3,998 | s. | 26 | w. | 12 | 11 | 4 | 13 | 5.4 | 0.0 | 0.0 |
| Thomasville | 273 | 49 | 58 | 29.87 | 30.17 | +.05 | 60.5 | +5.0 | 84 | 28 | 70 | 31 | 5 | 50 | 31 | | 54 | 50 | 78 | 2.27 | −2.2 | 6 | 3,546 | sw. | 21 | sw. | 12 | 7 | 9 | 12 | 6.0 | 0.0 | 0.0 |
| Pensacola | 56 | 149 | 185 | 30.10 | 30.16 | +.05 | 59.8 | +4.3 | 73 | 26 | 66 | 4 | 37 | 54 | 21 | | 57 | 54 | 86 | 2.02 | −2.5 | 9 | 8,488 | se. | 34 | sw. | 25 | 5 | 8 | 15 | 6.7 | 0.0 | 0.0 |
| Anniston | 741 | 9 | 57 | 29.38 | 30.19 | +.07 | 51.8 | +6.0 | 81 | 28 | 63 | 20 | 5 | 41 | 44 | | ..... | ..... | ..... | 1.91 | −2.7 | 13 | 4,740 | s. | 27 | nw. | 25 | 9 | 10 | 9 | 5.1 | 0.0 | 0.0 |
| Birmingham | 709 | 11 | 48 | 29.40 | 30.18 | +.06 | 52.6 | +4.3 | 82 | 25 | 63 | 24 | 5 | 42 | 39 | | 46 | 40 | 69 | 1.94 | −2.8 | 10 | 5,577 | s. | 25 | s. | 20 | 5 | 11 | 12 | 5.8 | 0.0 | 0.0 |
| Mobile | 57 | 125 | 161 | 30.09 | 30.15 | +.04 | 59.4 | +6.2 | 79 | 25 | 67 | 36 | 4 | 52 | 22 | | 55 | 52 | 84 | 3.33 | −2.0 | 8 | 7,064 | s. | 30 | n. | 17 | 3 | 15 | 10 | 6.5 | 0.0 | 0.0 |
| Montgomery | 223 | 100 | 112 | 29.92 | 30.18 | +.06 | 56.6 | +5.3 | 84 | 25 | 66 | 31 | 5 | 47 | 33 | | 51 | 46 | 75 | 1.69 | −3.8 | 12 | 4,943 | se. | 25 | sw. | 12 | 10 | 8 | 10 | 5.5 | 0.0 | 0.0 |
| Corinth | 409 | 6 | .... | ..... | ..... | ..... | 45.8 | ..... | 82 | 25 | 59 | 20 | 5 | 33 | 48 | | ..... | ..... | ..... | 2.90 | ..... | 6 | ..... | s. | ..... | ..... | ..... | 8 | 13 | 7 | .... | 0.0 | 0.0 |
| Jackson | 304 | 5 | .... | ..... | ..... | ..... | 56.2 | ..... | 89 | 25 | 67 | 26 | 4 | 45 | 39 | | ..... | ..... | ..... | 2.85 | ..... | 9 | ..... | se. | ..... | ..... | ..... | 9 | 12 | 7 | .... | 0.0 | 0.0 |
| Meridian | 375 | 85 | 93 | 29.75 | 30.15 | +.04 | 55.6 | +6.5 | 85 | 25 | 66 | 29 | 5 | 46 | 34 | | 50 | 46 | 76 | 1.72 | −3.2 | 12 | 4,645 | sw. | 25 | nw. | 25 | 6 | 11 | 11 | 6.0 | 0.0 | 0.0 |
| Vicksburg | 247 | 65 | 74 | 29.88 | 30.16 | +.06 | 55.6 | +4.7 | 84 | 25 | 65 | 27 | 1 | 46 | 30 | | 49 | 43 | 69 | 2.40 | −2.2 | 9 | 5,481 | se. | 24 | s. | 12 | 7 | 10 | 11 | 6.1 | 0.0 | 0.0 |
| New Orleans | 51 | 76 | 84 | 30.09 | 30.14 | +.05 | 63.0 | +6.7 | 83 | 28 | 70 | 40 | 4 | 56 | 25 | | 58 | 56 | 84 | 2.21 | −2.3 | 8 | 4,874 | s. | 23 | sw. | 24 | 4 | 13 | 11 | 6.4 | 0.0 | 0.0 |
| ***West Gulf States.*** | | | | | | | **52.6** | **+3.0** | | | | | | | | | | | **74** | **0.98** | **−1.8** | | | | | | | | | **5.8** | | |
| Shreveport | 249 | 77 | 93 | 29.85 | 30.13 | +0.04 | 55.1 | +5.1 | 89 | 25 | 65 | 27 | 1 | 45 | 33 | | 48 | 42 | 68 | 0.16 | −3.4 | 3 | 5,959 | s. | 29 | se. | 27 | 12 | 5 | 11 | 5.5 | 0.0 | 0.0 |
| Bentonville | 1,303 | 11 | 44 | 28.67 | 30.04 | −.06 | 40.5 | +2.0 | 79 | 24 | 54 | 4 | 1 | 28 | 49 | | ..... | ..... | ..... | 0.77 | −1.8 | 3 | 5,585 | s. | 28 | s. | 8 | 16 | 4 | 8 | 4.2 | T. | 0.0 |
| Fort Smith | 457 | 79 | 94 | 29.60 | 30.09 | −.01 | 45.2 | +3.4 | 84 | 24 | 57 | −13 | 1 | 33 | 42 | | 39 | 32 | 62 | 0.95 | −1.8 | 3 | 6,788 | e. | 39 | w. | 25 | 11 | 9 | 8 | 4.5 | 0.3 | 0.0 |
| Little Rock | 357 | 139 | 147 | 29.73 | 30.12 | +.01 | 48.0 | +3.9 | 87 | 25 | 58 | 17 | 1 | 38 | 43 | | 42 | 36 | 68 | 0.98 | −3.2 | 4 | 7,431 | s. | 51 | nw. | 25 | 10 | 5 | 13 | 5.7 | 0.0 | 0.0 |
| Brownsville | 57 | 4 | 26 | ..... | ..... | ..... | 65.2 | ..... | 88 | 26 | 76 | 31 | 2 | 54 | 33 | | ..... | ..... | ..... | 0.81 | ..... | 8 | ..... | s. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.0 | 0.0 |
| Corpus Christi | 20 | 69 | 77 | 30.07 | 30.09 | +.04 | 57.6 | −0.1 | 84 | 25 | 66 | 28 | 2 | 50 | 29 | | 53 | 52 | 89 | 0.51 | −1.5 | 8 | 8,678 | se. | 54 | se. | 27 | 5 | 7 | 16 | 7.1 | 0.0 | 0.0 |
| Dallas | 512 | 109 | 117 | 29.56 | 30.12 | ..... | 52.0 | ..... | 93 | 25 | 64 | 12 | 1 | 40 | 42 | | ..... | ..... | ..... | 0.63 | ..... | 6 | 7,464 | s. | 46 | se. | 27 | 8 | 9 | 11 | 5.4 | 0.2 | 0.0 |
| Fort Worth | 670 | 106 | 114 | 29.36 | 30.08 | +.01 | 52.0 | +3.9 | 93 | 25 | 65 | 12 | 1 | 39 | 42 | | 44 | 36 | 61 | 0.01 | −1.3 | 1 | 8,666 | s. | 40 | s. | 27 | 11 | 6 | 11 | 5.1 | T. | 0.0 |
| Galveston | 54 | 106 | 114 | 30.06 | 30.12 | +.05 | 57.0 | +1.4 | 74 | 25 | 62 | 31 | 2 | 52 | 22 | | 54 | 53 | 91 | 1.11 | −2.0 | 6 | 8,028 | se. | 32 | ne. | 20 | 7 | 3 | 18 | 7.0 | 0.0 | 0.0 |
| Houston | 138 | 111 | 121 | 29.95 | 30.11 | ..... | 59.1 | +5.1 | 85 | 25 | 68 | 26 | 2 | 50 | 31 | | ..... | ..... | ..... | 1.69 | ..... | 8 | 6,253 | se. | 32 | se. | 27 | 8 | 5 | 15 | 6.6 | 0.0 | 0.0 |
| Palestine | 510 | 64 | 72 | 29.56 | 30.10 | +.02 | 54.3 | +3.4 | 88 | 25 | 64 | 18 | 1 | 44 | 35 | | 49 | 46 | 81 | 1.02 | −2.4 | 11 | 6,610 | s. | 36 | se. | 27 | 7 | 4 | 17 | 6.3 | 0.0 | 0.0 |
| Port Arthur | 34 | 58 | 66 | 30.07 | 30.11 | ..... | 57.6 | ..... | 78 | 25 | 66 | 31 | 3 | 50 | 29 | | 54 | 52 | 90 | 2.83 | ..... | 11 | 6,897 | s. | 31 | sw. | 25 | 7 | 6 | 15 | 6.4 | T. | 0.0 |
| San Antonio | 701 | 119 | 132 | 29.35 | 30.08 | +.03 | 56.6 | +2.2 | 90 | 27 | 67 | 23 | 1 | 46 | 33 | | 49 | 44 | 71 | 1.10 | −0.7 | 10 | 5,973 | ne. | 31 | ne. | 9 | 7 | 11 | 10 | 5.7 | 0.0 | 0.0 |
| Taylor | 582 | 55 | 63 | 29.50 | 30.12 | +.06 | 53.6 | +2.3 | 87 | 25 | 65 | 16 | 1 | 42 | 38 | | ..... | ..... | ..... | 2.59 | 0.6 | 12 | 7,946 | n. | 49 | s. | 27 | 7 | 4 | 17 | 6.8 | T. | 0.0 |

TABLE I.—*Climatological data for Weather Bureau stations, February, 1918*—Continued.

| Districts and stations. | Elevation of instruments. | | | Pressure. | | | Temperature of the air. | | | | | | | | | | | | Mean wet thermometer. | Mean temperature of the dew point. | Mean relative humidity. | Precipitation. | | | Wind. | | | | | | Clear days. | Partly cloudy days. | Cloudy days. | Average cloudiness, tenths. | Total snowfall. | Snow on ground at end of month. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barometer above sealevel. | Thermometer above ground. | Anemometer above ground. | Station, reduced to mean of 24 hours. | Sealevel, reduced to mean of 24 hours. | Departure from normal. | Mean max.+mean min.÷2. | Departure from normal. | Maximum. | Date. | Mean maximum. | Minimum. | Date. | Mean minimum. | Greatest daily range. | | | | | | Total. | Departure from normal. | Days with 0.01 inch or more. | Total movement. | Prevailing direction. | Maximum velocity. Miles per hour. | Maximum velocity. Direction. | Maximum velocity. Date. | | | | | | | |
| *Ohio Valley and Tennessee.* | *Ft.* | *Ft.* | *Ft.* | *In.* | *In.* | *In.* | °*F.* | °*F.* | °*F* | | °*F* | °*F.* | | °*F* | °*F.* | | °*F.* | °*F.* | % | *In.* | *In.* | | *Miles.* | | | | | | | | | *0–10* | *In.* | *In.* |
| | | | | | | | **38.0** | **+2.4** | | | | | | | | | | | **75** | **2.25** | **−1.3** | | | | | | | | | | | **6.1** | | |
| Chattanooga | 762 | 189 | 213 | 29.35 | 30.18 | +0.05 | 47.6 | +3.9 | 78 | 25 | 58 | 14 | 5 | 38 | 36 | | 41 | 35 | 66 | 3.68 | −1.3 | 12 | 6,049 | s. | 53 | nw. | 25 | 5 | 11 | 12 | 6.4 | 0.0 | 0.0 |
| Knoxville | 996 | 102 | 111 | 29.07 | 30.15 | + .03 | 45.2 | +4.4 | 76 | 25 | 55 | 12 | 5 | 35 | 39 | | 41 | 37 | 78 | 2.37 | −2.5 | 11 | 4,844 | sw. | 50 | s. | 25 | 8 | 11 | 9 | 5.5 | 0.5 | 0.0 |
| Memphis | 399 | 76 | 97 | 29.73 | 30.17 | + .06 | 46.8 | +3.5 | 80 | 25 | 56 | 16 | 1 | 38 | 34 | | 42 | 37 | 71 | 2.24 | −2.1 | 6 | 7,317 | s. | 60 | nw. | 25 | 13 | 3 | 12 | 5.3 | 0.0 | 0.0 |
| Nashville | 546 | 168 | 191 | 29.56 | 30.16 | + .04 | 44.7 | +3.6 | 78 | 28 | 55 | 11 | 4 | 34 | 40 | | 40 | 34 | 70 | 1.54 | −2.8 | 8 | 8,135 | s. | 60 | nw. | 25 | 6 | 12 | 10 | 5.8 | 1.0 | 0.0 |
| Lexington | 989 | 193 | 230 | 29.05 | 30.16 | + .05 | 37.9 | +2.3 | 75 | 28 | 48 | −1 | 4 | 28 | 38 | | | | | 1.92 | −1.3 | 9 | 11,731 | sw. | 60 | sw. | 12 | 8 | 9 | 11 | 5.8 | 0.1 | 0.0 |
| Louisville | 525 | 219 | 255 | 29.54 | 30.14 | + .03 | 37.9 | +1.3 | 77 | 28 | 48 | 0 | 4 | 28 | 37 | | 34 | 28 | 70 | 1.90 | −1.8 | 6 | 10,294 | s. | 65 | w. | 25 | 6 | 12 | 10 | 6.0 | T. | 0.0 |
| Evansville | 431 | 139 | 175 | 29.64 | 30.12 | + .01 | 37.3 | +1.5 | 75 | 28 | 47 | 1 | 4 | 28 | 38 | | 34 | 30 | 76 | 0.38 | −2.7 | 5 | 9,616 | s. | 55 | w. | 25 | 5 | 14 | 9 | 5.9 | T. | 0.0 |
| Indianapolis | 822 | 194 | 230 | 29.17 | 30.08 | − .02 | 31.9 | +1.2 | 64 | 14 | 41 | −8 | 4 | 22 | 38 | | 28 | 24 | 76 | 2.49 | −0.6 | 8 | 10,106 | sw. | 71 | s. | 25 | 9 | 7 | 12 | 5.8 | T. | 0.0 |
| Terre Haute | 575 | 96 | 129 | 29.44 | 30.08 | | 32.6 | | 67 | 14 | 42 | −7 | 4 | 23 | 41 | | 29 | 25 | 77 | 2.05 | | 8 | 8,519 | s. | 48 | nw. | 25 | 7 | 11 | 10 | 5.9 | T. | 0.0 |
| Cincinnati | 628 | 11 | 51 | 29.40 | 30.11 | + .01 | 34.5 | +2.1 | 72 | 28 | 45 | −5 | 5 | 24 | 36 | | 31 | 27 | 77 | 1.61 | −1.6 | 8 | 7,142 | sw. | 51 | sw. | 12 | 9 | 5 | 14 | 6.2 | T. | 0.0 |
| Columbus | 824 | 173 | 222 | 29.19 | 30.09 | .00 | 31.2 | +0.2 | 68 | 14 | 40 | −10 | 5 | 22 | 34 | | 28 | 24 | 74 | 2.55 | −0.5 | 10 | 9,895 | sw. | 64 | nw. | 25 | 8 | 5 | 15 | 6.5 | 1.1 | 0.0 |
| Dayton | 899 | 181 | 216 | 29.07 | 30.06 | | 32.1 | +2.1 | 67 | 14 | 42 | −6 | 5 | 22 | 34 | | 29 | 26 | 79 | 2.53 | −0.6 | 10 | 9,250 | sw. | 60 | nw. | 25 | 6 | 9 | 13 | 6.5 | 0.4 | 0.0 |
| Pittsburgh | 842 | 353 | 410 | 29.15 | 30.08 | − .01 | 32.7 | +0.7 | 64 | 14 | 43 | −11 | 5 | 23 | 49 | | 28 | 23 | 71 | 1.87 | −0.8 | 13 | 9,506 | sw. | 56 | w. | 26 | 7 | 5 | 16 | 6.8 | 2.3 | 0.0 |
| Elkins | 1,940 | 59 | 67 | 30.00 | 30.13 | + .03 | 34.6 | +3.1 | 74 | 28 | 47 | −7 | 5 | 22 | 41 | | 30 | 27 | 79 | 3.61 | +0.4 | 14 | 5,357 | w. | 40 | w. | 26 | 5 | 8 | 15 | 7.1 | 6.5 | 0.0 |
| Parkersburg | 638 | 77 | 84 | 29.45 | 30.13 | + .03 | 36.8 | +2.9 | 73 | 28 | 48 | −6 | 5 | 26 | 41 | | 32 | 29 | 80 | 2.81 | −0.4 | 12 | 5,517 | nw. | 48 | nw. | 25 | 8 | 7 | 13 | 6.3 | 1.8 | 0.0 |
| *Lower Lakes Region.* | | | | | | | **24.5** | **−0.2** | | | | | | | | | | | **80** | **2.25** | **−0.2** | | | | | | | | | | | **6.6** | | |
| Buffalo | 767 | 247 | 280 | 29.14 | 30.00 | −0.06 | 23.1 | −0.9 | 54 | 25 | 32 | −12 | 5 | 14 | 42 | | 21 | 18 | 81 | 2.46 | −0.4 | 15 | 16,710 | sw. | 84 | w. | 26 | 3 | 8 | 17 | 7.0 | 6.8 | 3.0 |
| Canton | 448 | 10 | 61 | 29.49 | 30.00 | | 15.6 | −2.4 | 51 | 26 | 26 | −27 | 5 | 5 | 53 | | | | | 3.73 | +1.2 | 13 | 9,296 | sw. | 62 | w. | 26 | 8 | 5 | 15 | 6.5 | 16.5 | 1.0 |
| Oswego | 335 | 76 | 91 | 29.63 | 30.02 | − .04 | 20.4 | −3.5 | 48 | 12 | 30 | −18 | 5 | 10 | 45 | | 19 | 17 | 86 | 1.89 | −0.7 | 18 | 8,823 | s. | 50 | w. | 26 | 2 | 8 | 18 | 7.7 | 14.7 | 6.5 |
| Rochester | 523 | 97 | 113 | 29.42 | 30.02 | − .04 | 23.7 | −0.2 | 55 | 25 | 34 | −11 | 5 | 14 | 50 | | 21 | 17 | 77 | 2.67 | −0.2 | 18 | 7,833 | sw. | 50 | w. | 26 | 3 | 9 | 16 | 7.7 | 12.7 | 1.0 |
| Syracuse | 597 | 97 | 113 | 29.36 | 30.03 | − .04 | 23.2 | −0.6 | 54 | 20 | 34 | −19 | 5 | 12 | 51 | | | | | 2.02 | +0.2 | 19 | 10,365 | s. | 56 | w. | 26 | 3 | 11 | 14 | 7.3 | 15.6 | 1.0 |
| Erie | 714 | 130 | 166 | 29.22 | 30.02 | − .05 | 26.1 | 0.0 | 58 | 19 | 36 | −13 | 5 | 16 | 45 | | 24 | 20 | 79 | 1.41 | −1.4 | 14 | 11,865 | s. | 56 | sw. | 12 | 2 | 13 | 13 | 6.7 | 5.1 | 0.0 |
| Cleveland | 762 | 190 | 201 | 29.20 | 30.05 | − .02 | 28.2 | +1.4 | 62 | 14 | 38 | −12 | 5 | 19 | 37 | | 25 | 22 | 79 | 1.48 | −1.1 | 14 | 11,988 | sw. | 66 | w. | 26 | 4 | 10 | 14 | 7.1 | 1.8 | 0.0 |
| Sandusky | 629 | 62 | 103 | 29.34 | 30.04 | − .03 | 28.2 | +1.1 | 65 | 14 | 38 | −14 | 5 | 19 | 41 | | 25 | 21 | 76 | 1.25 | −1.1 | 8 | 10,842 | sw. | 58 | w. | 25 | 5 | 14 | 9 | 6.1 | 1.3 | 0.0 |
| Toledo | 628 | 208 | 243 | 29.34 | 30.05 | − .02 | 27.7 | +0.9 | 60 | 14 | 38 | −13 | 5 | 18 | 36 | | 24 | 21 | 80 | 1.99 | 0.0 | 9 | 12,035 | sw. | 62 | w. | 25 | 11 | 9 | 8 | 5.4 | 2.0 | 0.0 |
| Fort Wayne | 856 | 113 | 124 | 29.11 | 30.07 | | 28.5 | +2.7 | 63 | 14 | 38 | −10 | 5 | 19 | 42 | | 25 | 20 | 77 | 2.27 | | 10 | 8,635 | sw. | 44 | nw. | 25 | 10 | 8 | 10 | 5.2 | 1.7 | 0.0 |
| Detroit | 730 | 218 | 245 | 29.21 | 30.03 | − .03 | 24.5 | −0.5 | 57 | 14 | 34 | −16 | 5 | 15 | 33 | | 22 | 19 | 82 | 3.56 | +1.4 | 11 | 9,526 | sw. | 58 | nw. | 26 | 8 | 10 | 10 | 5.8 | 4.8 | 0.5 |
| *Upper Lakes Region.* | | | | | | | **17.0** | **−2.2** | | | | | | | | | | | **83** | **2.06** | **+0.3** | | | | | | | | | | | **6.1** | | |
| Alpena | 609 | 13 | 92 | 29.29 | 29.99 | −0.04 | 13.8 | −4.0 | 49 | 24 | 24 | −24 | 1 | 4 | 34 | | 13 | 11 | 86 | 0.92 | −0.9 | 9 | 8,159 | nw. | 54 | nw. | 26 | 6 | 12 | 10 | 5.9 | 6.3 | 2.0 |
| Escanaba | 612 | 54 | 60 | 29.30 | 30.00 | − .06 | 12.2 | −3.1 | 49 | 24 | 21 | −26 | 1 | 3 | 33 | | 11 | 9 | 90 | 1.78 | +0.4 | 5 | 6,910 | s. | 46 | n. | 14 | 11 | 7 | 10 | 5.4 | 15.4 | 9.0 |
| Grand Haven | 632 | 54 | 92 | 29.30 | 30.02 | − .03 | 21.6 | −2.6 | 54 | 14 | 30 | −14 | 5 | 14 | 38 | | 20 | 16 | 80 | 2.75 | +0.8 | 13 | 9,382 | sw. | 47 | nw. | 25 | 7 | 12 | 9 | 5.8 | 5.8 | 2.0 |
| Grand Rapids | 707 | 70 | 87 | 29.22 | 30.02 | − .03 | 22.4 | −3.1 | 53 | 14 | 31 | −12 | 5 | 14 | 39 | | 21 | 17 | 78 | 3.81 | +1.9 | 11 | 4,963 | w. | 32 | nw. | 25 | 5 | 13 | 10 | 6.6 | 5.6 | 3.5 |
| Houghton | 684 | 62 | 99 | 29.23 | 30.00 | − .05 | 10.8 | −5.2 | 44 | 23 | 20 | −23 | 5 | 2 | 33 | | | | | 0.63 | −1.1 | 14 | 6,983 | w. | 42 | w. | 24 | 1 | 7 | 20 | 8.4 | 6.8 | 13.0 |
| Lansing | 878 | 11 | 62 | 29.04 | 30.02 | | 21.8 | +0.2 | 52 | 14 | 32 | −21 | 5 | 12 | 39 | | 19 | 16 | 81 | 3.04 | +1.0 | 14 | 5,830 | sw. | 42 | nw. | 25 | 8 | 8 | 12 | 6.0 | 6.3 | 2.5 |
| Ludington | 637 | 60 | 66 | 29.28 | 30.00 | | 19.4 | | 45 | 14 | 27 | −19 | 5 | 12 | 37 | | 18 | 16 | 87 | 1.40 | | 9 | 8,387 | s. | 41 | n. | 25 | 5 | 14 | 9 | 6.1 | 4.6 | 4.7 |
| Marquette | 734 | 77 | 111 | 29.17 | 30.01 | − .04 | 12.8 | −3.1 | 47 | 24 | 22 | −21 | 1 | 4 | 35 | | 11 | 8 | 85 | 2.12 | +0.4 | 13 | 7,485 | nw. | 47 | sw. | 22 | 5 | 11 | 12 | 6.6 | 22.6 | 30.5 |
| Port Huron | 638 | 70 | 120 | 29.29 | 30.01 | − .04 | 21.0 | −1.0 | 53 | 24 | 31 | −22 | 5 | 11 | 36 | | 19 | 16 | 84 | 2.70 | +0.6 | 12 | 9,224 | sw. | 57 | nw. | 25 | 8 | 12 | 8 | 5.2 | 6.7 | 2.4 |
| Saginaw | 641 | 48 | 82 | 29.28 | 30.01 | | 20.2 | | 49 | 14 | 30 | −23 | 5 | 11 | 38 | | 18 | 16 | 85 | 2.98 | +0.9 | 12 | 7,884 | sw. | 54 | nw. | 25 | 4 | 11 | 13 | 6.8 | 7.4 | 3.8 |
| Sault Sainte Marie | 614 | 11 | 61 | 29.27 | 30.01 | − .02 | 8.5 | −4.9 | 39 | 24 | 18 | −31 | 5 | −1 | 37 | | 7 | 4 | 81 | 1.47 | +0.1 | 15 | 6,146 | w. | 47 | ne. | 14 | 9 | 9 | 10 | 5.9 | 15.1 | 22.0 |
| Chicago | 823 | 140 | 310 | 29.13 | 30.05 | − .03 | 27.2 | +1.8 | 61 | 14 | 35 | −10 | 4 | 19 | 38 | | 25 | 21 | 77 | 2.81 | +0.6 | 13 | 9,386 | sw. | 48 | w. | 19 | 6 | 13 | 9 | 5.8 | 8.4 | 2.6 |
| Green Bay | 617 | 109 | 144 | 29.31 | 30.00 | − .06 | 15.8 | −1.4 | 47 | 24 | 24 | −23 | 1 | 7 | 36 | | 14 | 10 | 77 | 1.21 | −0.4 | 4 | 8,451 | sw. | 57 | ne. | 14 | 7 | 11 | 10 | 6.2 | 5.6 | 2.5 |
| Milwaukee | 681 | 119 | 133 | 29.25 | 30.01 | − .05 | 22.2 | +0.3 | 50 | 24 | 30 | −13 | 4 | 14 | 40 | | 21 | 18 | 81 | 2.32 | +0.4 | 11 | 8,021 | sw. | 37 | e. | 14 | 13 | 8 | 7 | 4.8 | 6.5 | 4.2 |
| Duluth | 1,133 | 11 | 47 | 28.72 | 30.00 | − .08 | 10.8 | −2.8 | 43 | 24 | 20 | −22 | 1 | 2 | 35 | | 9 | 7 | 88 | 0.28 | −0.7 | 9 | 9,703 | sw. | 50 | nw. | 25 | 8 | 6 | 14 | 5.9 | 2.9 | 3.5 |
| *North Dakota.* | | | | | | | **11.5** | **+4.6** | | | | | | | | | | | **83** | **0.20** | **−0.3** | | | | | | | | | | | **4.9** | | |
| Moorhead | 940 | 8 | 57 | 29.00 | 30.07 | −0.04 | 12.0 | +5.0 | 52 | 23 | 24 | −23 | 20 | 0 | 48 | | 10 | 7 | 83 | 0.35 | −0.4 | 6 | 6,715 | nw. | 34 | nw. | 25 | 18 | 2 | 8 | 3.6 | 3.5 | T. |
| Bismarck | 1,674 | 8 | 57 | 28.21 | 30.09 | − .03 | 14.2 | +5.9 | 54 | 10 | 25 | −29 | 21 | 3 | 46 | | 12 | 9 | 82 | 0.29 | −0.2 | 6 | 6,745 | nw. | 33 | nw. | 19 | 11 | 9 | 8 | 5.1 | 4.5 | 2.0 |
| Devils Lake | 1,482 | 11 | 44 | 28.36 | 30.03 | − .08 | 8.6 | +4.1 | 46 | 23 | 20 | −30 | 20 | −3 | 44 | | 7 | 5 | 87 | 0.14 | −0.4 | 4 | 8,191 | sw. | 39 | n. | 24 | 10 | 10 | 8 | 5.6 | 2.0 | T. |
| Ellendale | 1,457 | 10 | 56 | 28.42 | 30.05 | | 13.0 | | 51 | 10 | 25 | −35 | 21 | 1 | 49 | | | | | 0.50 | | 4 | 10,609 | nw. | 57 | ne. | 14 | 7 | 14 | 7 | 5.1 | 5.4 | T. |
| Grand Forks | 835 | 12 | 89 | | | | 8.4 | | 48 | 23 | 21 | −28 | 20 | −4 | 49 | | | | | 0.27 | | 7 | | nw. | | | | 17 | 6 | 5 | 3.6 | 2.6 | T. |
| Williston | 1,872 | 41 | 48 | 27.96 | 30.04 | − .07 | 11.2 | +3.3 | 45 | 23 | 21 | −33 | 20 | 1 | 44 | | 10 | 7 | 80 | 0.13 | −0.3 | 4 | 5,970 | sw. | 34 | se. | 6 | 8 | 13 | 7 | 5.3 | 1.3 | T. |
| *Upper Mississippi Valley.* | | | | | | | **26.7** | **+2.2** | | | | | | | | | | | **78** | **1.19** | **−0.6** | | | | | | | | | | | **5.3** | | |
| Minneapolis | 918 | 10 | 208 | | | | 18.0 | | 48 | 11 | 28 | −20 | 1 | 8 | 36 | | | | | 0.55 | −0.2 | 5 | 8,617 | nw. | 54 | ne. | 14 | 9 | 10 | 9 | 5.1 | 4.9 | 0.0 |
| St. Paul | 837 | 201 | 236 | 29.08 | 30.03 | −0.06 | 17.4 | +2.4 | 49 | 11 | 28 | −25 | 1 | 7 | 38 | | | | | 0.69 | −0.2 | 5 | 8,716 | nw. | 48 | n. | 25 | 10 | 12 | 6 | 4.8 | 5.0 | T. |
| La Crosse | 714 | 11 | 48 | 29.22 | 30.03 | − .05 | 19.2 | +0.8 | 54 | 24 | 29 | −28 | 1 | 9 | 32 | | | | | 0.64 | −0.4 | 6 | 4,264 | nw. | 27 | nw. | 25 | 8 | 7 | 13 | 5.8 | 4.9 | 0.0 |
| Madison | 974 | 70 | 78 | 28.94 | 30.04 | − .03 | 19.5 | −0.1 | 51 | 24 | 28 | −29 | 1 | 11 | 34 | 17 | 14 | 80 | | 1.30 | −0.2 | 10 | 6,786 | sw. | 38 | nw. | 25 | 7 | 10 | 11 | 6.0 | 5.4 | 1.5 |
| Wausau | 1,247 | 4 | | 28.60 | 30.00 | | 13.2 | | 48 | 11 | 24 | −30 | 1 | 2 | 37 | | | | | 0.79 | | 4 | | nw. | | | | 14 | 3 | 11 | 4.8 | 5.3 | 5.0 |
| Charles City | 1,015 | 10 | 49 | 28.92 | 30.04 | − .06 | 19.0 | +3.9 | 54 | 24 | 30 | −27 | 1 | 8 | 36 | 16 | 14 | 84 | | 0.24 | −0.7 | 4 | 5,339 | nw. | 26 | ne. | 14 | 6 | 15 | 7 | 5.8 | 2.2 | 0.0 |
| Davenport | 606 | 71 | 79 | 29.37 | 30.06 | − .04 | 26.8 | +3.0 | 63 | 14 | 36 | −14 | 4 | 17 | 40 | 24 | 20 | 80 | | 1.17 | −0.4 | 11 | 6,241 | sw. | 38 | sw. | 14 | 7 | 11 | 10 | 5.7 | 6.1 | 1.8 |
| Des Moines | 861 | 84 | 97 | 29.10 | 30.04 | − .07 | 26.4 | +2.3 | 61 | 23 | 37 | −17 | 4 | 16 | 39 | 23 | 19 | 75 | | 1.45 | +0.4 | 8 | 5,838 | sw. | 37 | nw. | 25 | 10 | 10 | 8 | 5.2 | 8.8 | 1.4 |
| Dubuque | 698 | 81 | 96 | 29.28 | 30.06 | − .03 | 23.0 | +1.4 | 56 | 23 | 32 | −21 | 1 | 14 | 33 | 20 | 17 | 80 | | 1.37 | 0.0 | 9 | 4,935 | nw. | 35 | nw. | 25 | 8 | 9 | 11 | 5.5 | 5.3 | 1.3 |
| Keokuk | 614 | 64 | 78 | 29.38 | 30.08 | − .03 | 29.9 | +3.3 | 65 | 23 | 41 | −13 | 4 | 19 | 45 | 27 | 22 | 75 | | 1.15 | −0.5 | 8 | 6,739 | nw. | 48 | sw. | 14 | 11 | 10 | 7 | 4.5 | 0.5 | T. |
| Cairo | 356 | 87 | 93 | 29.72 | 30.12 | .00 | 40.4 | +2.8 | 78 | 28 | 50 | 9 | 4 | 30 | 43 | 36 | 32 | 75 | | 1.03 | −2.3 | 4 | 7,677 | s. | 42 | nw. | 25 | 7 | 9 | 12 | 5.8 | 0.8 | 0.0 |
| Peoria | 609 | 11 | 45 | 29.39 | 30.08 | − .02 | 27.9 | +2.0 | 67 | 14 | 38 | −15 | 4 | 17 | 42 | 25 | 23 | 86 | | 1.64 | −1.0 | 8 | 6,237 | s. | 46 | sw. | 14 | 10 | 9 | 9 | 5.0 | 0.4 | 0.0 |
| Springfield, Ill. | 644 | 10 | 91 | 29.37 | 30.07 | − .03 | 30.8 | +1.7 | 68 | 14 | 40 | −10 | 4 | 21 | 46 | 27 | 23 | 76 | | 1.71 | −1.1 | 8 | 7,364 | s. | 44 | sw. | 14 | 12 | 4 | 12 | 5.2 | 0.6 | 0.0 |
| Hannibal | 534 | 74 | 109 | 29.46 | 30.06 | − .05 | 31.8 | +2.7 | 68 | 23 | 44 | −9 | 4 | 20 | 49 | | | | | 0.88 | −0.7 | 7 | 7,737 | sw. | 54 | sw. | 14 | 13 | 7 | 8 | 4.7 | 0.1 | 0.0 |
| St. Louis | 567 | 265 | 303 | 29.46 | 30.08 | − .03 | 35.6 | +2.1 | 70 | 19 | 45 | 2 | 4 | 26 | 51 | 31 | 26 | 71 | | 2.09 | −0.7 | 7 | 11,243 | s. | 65 | sw. | 14 | 12 | 7 | 9 | 5.2 | 0.2 | 0.0 |
| *Missouri Valley.* | | | | | | | **28.2** | **+3.8** | | | | | | | | | | | **75** | **0.94** | **0.0** | | | | | | | | | | | **4.4** | | |
| Columbia, Mo. | 781 | 11 | 84 | 29.16 | 30.06 | −0.05 | 33.7 | +3.6 | 69 | 23 | 45 | −4 | 1 | 22 | 48 | | | | | 1.30 | −0.8 | 6 | 7,145 | s. | 45 | sw. | 14 | 13 | 7 | 8 | 5.1 | T. | 0.0 |
| Kansas City | 963 | 161 | 181 | 29.00 | 30.07 | − .04 | 34.0 | +4.1 | 69 | 23 | 46 | −9 | 1 | 22 | 42 | 28 | 20 | 59 | | 1.53 | −0.1 | 5 | 9,829 | sw. | 53 | nw. | 25 | 15 | 8 | 5 | 3.8 | 0.1 | 0.0 |
| St. Joseph | 967 | 11 | 49 | 29.00 | 30.07 | | 31.8 | | 71 | 23 | 44 | −13 | 1 | 20 | 42 | 26 | 20 | 67 | | 1.07 | | 4 | 7,262 | nw. | 46 | nw. | 25 | 13 | 7 | 8 | 4.2 | 1.0 | 0.6 |
| Springfield, Mo. | 1,324 | 98 | 104 | 28.65 | 30.09 | − .02 | 37.6 | +4.0 | 72 | 23 | 49 | 1 | 1 | 26 | 50 | 34 | 30 | 77 | | 0.64 | −1.6 | 4 | 8,907 | s. | 46 | w. | 14 | 19 | 6 | 3 | 2.6 | T. | 0.0 |
| Iola | 984 | 11 | 50 | 28.98 | 30.07 | − .03 | 34.8 | +2.8 | 76 | 24 | 48 | −8 | 1 | 22 | 43 | | | | | 0.91 | −0.2 | 3 | 6,457 | n | 58 | ne. | 27 | 13 | 10 | 5 | 4.5 | T. | 0.0 |
| Topeka | 983 | 85 | 101 | | | | 33.8 | +3.8 | 78 | 23 | 47 | −9 | 1 | 20 | 46 | | | | | 1.28 | −0.1 | 4 | 8,485 | s. | 49 | w. | 14 | 17 | 6 | 5 | 3.3 | T. | 0.0 |
| Drexel | 1,299 | 10 | 54 | 28.62 | 30.06 | | 24.9 | | 63 | 23 | 36 | −17 | 1 | 14 | 33 | 21 | 18 | 83 | | 0.94 | | 7 | 8,491 | sw. | 36 | nw. | 25 | 11 | 8 | 9 | 5.1 | 8.6 | 0.5 |
| Lincoln | 1,189 | 11 | 84 | 28.75 | 30.07 | − .03 | 28.4 | +3.6 | 75 | 23 | 41 | −16 | 1 | 16 | 47 | 23 | 19 | 77 | | 1.22 | +0.5 | 7 | 8,102 | s. | 54 | nw. | 14 | 14 | 9 | 5 | 4.3 | 10.8 | 2.0 |
| Omaha | 1,105 | 115 | 122 | 28.84 | 30.08 | − .03 | 27.5 | +3.8 | 67 | 23 | 38 | −11 | 20 | 17 | 33 | 23 | 17 | 71 | | 1.05 | +0.3 | 8 | 6,550 | nw. | 45 | nw. | 25 | 13 | 5 | 10 | 4.7 | 10.5 | 0.7 |
| Valentine | 2,598 | 47 | 54 | 27.25 | 30.07 | − .02 | 24.4 | +3.2 | 65 | 10 | 37 | −22 | 20 | 12 | 53 | 21 | 17 | 79 | | 0.21 | −0.4 | 5 | 6,864 | w. | 40 | nw. | 14 | 12 | 11 | 5 | 4.7 | 2.2 | 0.0 |
| Sioux City | 1,135 | 94 | 164 | 28.80 | 30.07 | − .05 | 23.0 | +3.2 | 60 | 10 | 34 | −20 | 4 | 12 | 35 | 20 | 16 | 80 | | 0.84 | +0.3 | 3 | 8,238 | nw. | 51 | nw. | 25 | 12 | 9 | 7 | 4.6 | 7.2 | 0.0 |
| Huron | 1,306 | 59 | 74 | 28.62 | 30.08 | − .04 | 18.2 | +5.3 | 60 | 10 | 30 | −26 | 1 | 6 | 40 | 15 | 12 | 82 | | 0.65 | +0.2 | 5 | 7,688 | nw. | 40 | nw. | 25 | 15 | 9 | 4 | 4.2 | 4.0 | T. |
| Pierre | 1,572 | 70 | 75 | 28.35 | 30.09 | − .02 | 20.2 | +3.3 | 61 | 10 | 32 | −22 | 20 | 8 | 47 | 17 | 13 | 76 | | 0.63 | +0.2 | 5 | 5,859 | nw. | 52 | ne. | 14 | 8 | 14 | 6 | 4.8 | 10.8 | T. |
| Yankton | 1,233 | 49 | 57 | 28.67 | 30.04 | − .08 | 22.6 | +4.4 | 62 | 10 | 34 | −20 | 1 | 11 | 39 | | | | | 0.99 | +0.4 | 4 | 5,671 | nw. | 36 | nw. | 25 | 9 | 12 | 7 | 5.3 | 9.2 | T. |

TABLE 1.—*Climatological data for Weather Bureau stations, February, 1918*—Continued.

| Districts and stations. | Elevation of instruments. | | | Pressure. | | | Temperature of the air. | | | | | | | | | | | | Mean wet thermometer. | Mean temperature of the dew point. | Mean relative humidity. | Precipitation. | | | Wind. | | | | | Clear days. | Partly cloudy days. | Cloudy days. | Average cloudiness, tenths. | Total snowfall. | Snow on ground at end of month. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barometer above sealevel. | Thermometer above ground. | Anemometer above ground. | Station, reduced to mean of 24 hours. | Sealevel, reduced to mean of 24 hours. | Departure from normal. | Mean max.+mean min.÷2. | Departure from normal. | Maximum. | Date. | Mean maximum. | Minimum. | Date. | Mean minimum. | Greatest daily range. | | | | | | Total. | Departure from normal. | Days with 0.01 inch or more. | Total movement. | Prevailing direction. | Maximum velocity. Miles per hour. | Maximum velocity. Direction. | Maximum velocity. Date. | | | | | | |
| | *Ft.* | *Ft.* | *Ft.* | *In.* | *In.* | *In.* | °*F.* | °*F.* | °*F* | | °*F* | °*F.* | | °*F* | °*F.* | °*F.* | °*F.* | % | *In.* | *In.* | | *Miles.* | | | | | | | | *0–10* | *In.* | *In.* |
| *Northern Slope.* | | | | | | | **23.1** | **+1.6** | | | | | | | | | | **70** | **0.73** | **−0.1** | | | | | | | | | | **5.4** | | |
| Billings | 3,140 | 5 | | | | | 23.0 | | 50 | 10 | 34 | −23 | 20 | 12 | 49 | | | | 0.69 | | 5 | | sw. | | | | 9 | 14 | 5 | | 9.2 | 1.0 |
| Havre | 2,505 | 11 | 44 | 27.28 | 30.03 | −0.04 | 17.8 | +2.8 | 49 | 10 | 27 | −39 | 20 | 8 | 53 | 16 | 13 | 83 | 0.40 | −0.1 | 6 | 7,323 | sw. | 37 | sw. | 4 | 6 | 16 | 9 | 5.2 | 4.0 | 0.0 |
| Helena | 4,110 | 87 | 112 | 25.72 | 30.06 | − .05 | 23.7 | +1.5 | 60 | 10 | 30 | −16 | 20 | 14 | 36 | 20 | 13 | 66 | 0.38 | −0.4 | 8 | 4,834 | sw. | 38 | sw. | 7 | 8 | 7 | 13 | 6.1 | 5.2 | T. |
| Kalispell | 2,962 | 11 | 34 | 26.88 | 30.05 | − .03 | 21.7 | −2.1 | 54 | 10 | 30 | −18 | 20 | 13 | 31 | 19 | 15 | 76 | 0.90 | −0.6 | 14 | 3,910 | nw. | 26 | ne. | 17 | 5 | 10 | 13 | 6.3 | 8.2 | 3.0 |
| Miles City | 2,371 | 48 | 55 | 27.44 | 30.11 | + .02 | 18.5 | +1.7 | 49 | 10 | 29 | −36 | 20 | 8 | 52 | 16 | 13 | 83 | 0.49 | −0.1 | 3 | 4,201 | s. | 24 | ne. | 13 | 9 | 12 | 7 | 4.8 | 5.0 | 0.2 |
| Rapid City | 3,259 | 50 | 58 | 26.54 | 30.09 | + .01 | 24.7 | +1.2 | 65 | 10 | 37 | −19 | 20 | 12 | 52 | 20 | 12 | 62 | 0.45 | 0.0 | 3 | 6,195 | w. | 40 | n. | 24 | 10 | 11 | 7 | 4.6 | 5.4 | 0.0 |
| Cheyenne | 6,088 | 84 | 101 | 23.89 | 30.01 | − .02 | 29.4 | +3.1 | 66 | 10 | 42 | −13 | 19 | 17 | 45 | 23 | 12 | 51 | 0.89 | +0.3 | 8 | 12,968 | w. | 76 | w. | 5 | 8 | 15 | 5 | 5.1 | 11.8 | 3.5 |
| Lander | 5,372 | 60 | 68 | 24.55 | 30.07 | − .01 | 24.6 | +2.8 | 56 | 22 | 38 | −24 | 1 | 11 | 42 | 20 | 13 | 63 | 0.72 | +0.1 | 5 | 3,125 | w | 56 | w. | 5 | 9 | 12 | 7 | 5.4 | 8.4 | 3.6 |
| Sheridan | 3,790 | 10 | 47 | 26.02 | 30.07 | | 23.1 | | 58 | 23 | 36 | −22 | 1 | 10 | 64 | 18 | 13 | 71 | 0.19 | | 7 | 4,186 | nw. | 40 | w. | 2 | 7 | 8 | 13 | 6.8 | 2.2 | 0.4 |
| Yellowstone Park | 6,200 | 11 | 48 | 23.78 | 30.12 | + .02 | 18.2 | −1.4 | 44 | 10 | 28 | −17 | 19 | 8 | 38 | 16 | 11 | 72 | 2.03 | +0.2 | 14 | 6,766 | s. | 40 | nw. | 24 | 6 | 11 | 11 | 5.9 | 22.9 | 17.0 |
| North Platte | 2,821 | 11 | 51 | 27.06 | 30.09 | + .02 | 29.1 | +4.5 | 73 | 23 | 44 | −17 | 1 | 15 | 52 | 23 | 17 | 69 | 0.28 | −0.1 | 5 | 5,764 | w. | 36 | n. | 25 | 15 | 7 | 6 | 4.0 | 1.7 | T. |
| *Middle Slope.* | | | | | | | **37.2** | **+5.0** | | | | | | | | | | **57** | **0.79** | **0.0** | | | | | | | | | | **3.7** | | |
| Denver | 5,292 | 106 | 113 | 24.65 | 30.01 | 0.00 | 36.9 | +5.8 | 70 | 22 | 50 | 0 | 20 | 23 | 50 | 27 | 16 | 48 | 1.02 | +0.5 | 4 | 6,640 | se. | 43 | sw. | 26 | 16 | 8 | 4 | 3.5 | 13.3 | 7.8 |
| Pueblo | 4,685 | 80 | 86 | 25.23 | 30.00 | .00 | 37.4 | +5.6 | 72 | 22 | 53 | −8 | 1 | 21 | 56 | 28 | 14 | 44 | 0.79 | +0.3 | 4 | 6,321 | nw. | 48 | w. | 13 | 13 | 10 | 5 | 4.0 | 7.8 | 2.8 |
| Concordia | 1,392 | 50 | 58 | 28.56 | 30.08 | − .01 | 32.6 | +3.8 | 80 | 23 | 46 | −11 | 1 | 19 | 49 | 26 | 21 | 72 | 0.63 | −0.1 | 4 | 7,028 | nw. | 48 | nw. | 14 | 11 | 10 | 7 | 4.6 | 3.8 | 2.0 |
| Dodge City | 2,509 | 11 | 51 | 27.39 | 30.06 | .00 | 37.5 | +6.4 | 84 | 23 | 54 | −8 | 1 | 21 | 57 | 28 | 19 | 57 | 0.29 | −0.4 | 3 | 7,654 | nw. | 43 | nw. | 8 | 17 | 8 | 3 | 3.0 | 0.2 | 0.0 |
| Wichita | 1,358 | 139 | 158 | 28.58 | 30.06 | − .02 | 36.1 | +3.1 | 81 | 23 | 49 | −6 | 1 | 23 | 44 | 40 | 21 | 62 | 1.93 | +0.9 | 1 | 10,850 | s. | 59 | nw. | 14 | 14 | 10 | 4 | 3.4 | T. | 0.0 |
| Altus | 1,410 | 5 | | | | | 47.4 | | 92 | 24 | 62 | 6 | 1 | 32 | 56 | | | | 0.40 | | 1 | | s. | | | | 20 | 1 | 7 | | 0.0 | 0.0 |
| Muskogee | 652 | 4 | | | | | 41.7 | | 87 | 24 | 56 | 3 | 1 | 27 | 53 | | | | 0.30 | | 2 | | s. | | | | 10 | 3 | 15 | | 0.0 | 0.0 |
| Oklahoma | 1,214 | 10 | 47 | 28.77 | 30.08 | + .01 | 43.1 | +5.4 | 88 | 23 | 56 | 2 | 1 | 30 | 48 | 34 | 24 | 57 | 0.07 | −0.9 | 3 | 11,258 | s. | 48 | n. | 25 | 14 | 8 | 6 | 3.9 | T. | 0.0 |
| *Southern Slope.* | | | | | | | **49.5** | **+5.0** | | | | | | | | | | **45** | **0.11** | **−0.8** | | | | | | | | | | **3.6** | | |
| Abilene | 1,738 | 10 | 52 | 28.25 | 30.08 | +0.03 | 51.4 | +6.6 | 91 | 24 | 65 | 9 | 1 | 38 | 50 | 39 | 25 | 42 | 0.11 | −1.0 | 1 | 8,639 | s. | 44 | sw. | 5 | 12 | 7 | 9 | 4.7 | 0.0 | 0.0 |
| Amarillo | 3,676 | 10 | 49 | 26.26 | 30.04 | + .02 | 44.0 | +6.8 | 82 | 23 | 61 | 0 | 1 | 27 | 50 | 34 | 23 | 53 | 0.26 | −0.6 | 1 | 8,579 | sw. | 42 | n. | 8 | 24 | 4 | 0 | 2.4 | T. | 0.0 |
| Del Rio | 944 | 64 | 71 | 29.07 | 30.07 | + .07 | 56.6 | +3.0 | 96 | 25 | 69 | 19 | 2 | 44 | 43 | | | | 0.05 | −0.8 | 3 | 6,391 | e. | 38 | n. | 8 | 14 | 6 | 8 | 4.4 | 0.0 | 0.0 |
| Roswell | 3,566 | 75 | 85 | 26.38 | 30.02 | + .04 | 46.2 | +3.7 | 83 | 24 | 63 | 9 | 1 | 29 | 51 | 35 | 18 | 40 | 0.02 | −0.6 | 1 | 6,841 | s. | 46 | sw. | 18 | 17 | 10 | 1 | 2.9 | 0.0 | 0.0 |
| *Southern Plateau.* | | | | | | | **45.8** | **+1.0** | | | | | | | | | | **45** | **0.50** | **−0.2** | | | | | | | | | | **3.1** | | |
| El Paso | 3,762 | 110 | 133 | 26.21 | 30.00 | +0.05 | 51.8 | +2.9 | 80 | 26 | 65 | 24 | 1 | 39 | 39 | 40 | 24 | 37 | 0.01 | −0.4 | 1 | 9,266 | w. | 66 | sw. | 27 | 19 | 7 | 2 | 2.6 | T. | 0.0 |
| Santa Fe | 7,013 | 57 | 66 | 23.21 | 30.02 | + .04 | 35.8 | +3.8 | 58 | 23 | 46 | 8 | 1 | 26 | 31 | 29 | 21 | 57 | 1.14 | +0.3 | 9 | 5,395 | n. | 46 | sw. | 18 | 15 | 9 | 4 | 4.1 | 1.7 | 0.0 |
| Flagstaff | 6,908 | 8 | 57 | 23.31 | 29.98 | − .02 | 32.6 | +1.8 | 54 | 6 | 44 | 3 | 2 | 21 | 42 | | | | 1.50 | | 7 | | w. | 46 | w. | 7 | 18 | 5 | 5 | | 4.5 | T. |
| Phoenix | 1,108 | 76 | 81 | 28.85 | 30.02 | + .03 | 55.2 | +0.8 | 79 | 4 | 69 | 30 | 2 | 41 | 42 | 44 | 33 | 50 | 0.45 | −0.2 | 6 | 3,675 | e. | 36 | w. | 18 | 18 | 4 | 6 | 2.8 | 0.0 | 0.0 |
| Yuma | 141 | 9 | 54 | 29.88 | 30.03 | + .03 | 57.8 | −1.4 | 82 | 6 | 72 | 34 | 19 | 44 | 38 | 46 | 31 | 40 | 0.12 | −0.5 | 1 | 4,218 | n. | 26 | n. | 27 | 21 | 5 | 2 | 2.0 | 0.0 | 0.0 |
| Independence | 3,910 | 11 | 42 | 25.98 | 30.01 | − .05 | 41.8 | −1.9 | 71 | 12 | 54 | 14 | 19 | 29 | 39 | 33 | 18 | 43 | 0.77 | 0.0 | 6 | | n. | | | | 15 | 6 | 7 | 4.2 | 5.7 | 0.0 |
| Needles | 488 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Middle Plateau.* | | | | | | | **32.4** | **−0.5** | | | | | | | | | | **61** | **0.94** | **−0.2** | | | | | | | | | | **5.1** | | |
| Reno | 4,532 | 74 | 81 | 25.45 | 30.07 | −0.01 | 35.0 | −0.6 | 62 | 4 | 46 | 10 | 25 | 24 | 37 | 30 | 22 | 61 | 1.73 | −0.1 | 11 | 4,833 | w. | 47 | sw. | 13 | 12 | 5 | 11 | 5.0 | 13.7 | T. |
| Tonopah | 6,090 | 12 | 20 | 24.01 | 30.04 | | 32.8 | | 57 | 6 | 41 | 10 | 19 | 24 | 28 | 27 | 17 | 55 | 0.39 | −0.4 | 5 | 7,410 | se. | 38 | w. | 14 | 14 | 8 | 6 | 4.0 | 5.4 | T. |
| Winnemucca | 4,344 | 18 | 56 | 25.61 | 30.08 | − .01 | 32.1 | −1.2 | 57 | 6 | 44 | 1 | 15 | 20 | 33 | 28 | 22 | 66 | 0.79 | −0.1 | 7 | 5,045 | ne. | 46 | sw. | 13 | 11 | 4 | 13 | 5.6 | 4.1 | 0.0 |
| Modena | 5,479 | 10 | 43 | 24.60 | 30.04 | .00 | 31.8 | +0.2 | 59 | 11 | 46 | −5 | 1 | 17 | 49 | 26 | 14 | 52 | 0.97 | −0.2 | 7 | 8,627 | sw. | 60 | sw. | 13 | 11 | 11 | 6 | 4.4 | 4.0 | 0.0 |
| Salt Lake City | 4,360 | 163 | 203 | 25.64 | 30.10 | + .02 | 31.7 | −1.2 | 52 | 23 | 40 | 4 | 1 | 23 | 27 | 27 | 22 | 67 | 1.41 | 0.0 | 10 | 4,687 | nw. | 39 | nw. | 13 | 6 | 10 | 12 | 6.5 | 11.8 | 0.7 |
| Grand Junction | 4,602 | 82 | 96 | 25.40 | 30.06 | + .02 | 31.6 | +0.1 | 58 | 23 | 42 | −1 | 3 | 21 | 33 | 26 | 19 | 65 | 0.33 | −0.3 | 6 | 4,909 | se. | 52 | w. | 13 | 10 | 13 | 5 | 4.9 | 2.1 | 0.0 |
| *Northern Plateau.* | | | | | | | **33.6** | **+1.5** | | | | | | | | | | **69** | **0.92** | **−0.5** | | | | | | | | | | **6.9** | | |
| Baker | 3,471 | 48 | 53 | 26.41 | 30.07 | −0.05 | 29.0 | +1.1 | 50 | 6 | 37 | 8 | 19 | 21 | 27 | 26 | 21 | 72 | 0.43 | −0.9 | 12 | 5,112 | se. | 48 | sw. | 6 | 7 | 11 | 10 | 5.9 | 1.6 | T. |
| Boise | 2,739 | 78 | 86 | 27.18 | 30.10 | − .02 | 36.0 | +2.2 | 59 | 6 | 44 | 15 | 1 | 28 | 27 | 31 | 24 | 63 | 0.88 | −0.5 | 12 | 4,505 | se. | 36 | se. | 6 | 5 | 10 | 13 | 6.5 | 3.2 | 0.0 |
| Lewiston | 757 | 40 | 48 | 29.22 | 30.05 | − .06 | 37.8 | +1.6 | 60 | 6 | 45 | 16 | 1 | 30 | 22 | | | | 0.60 | −0.7 | 12 | 3,454 | e. | 23 | ne. | 9 | 3 | 8 | 17 | 7.2 | 1.6 | 0.0 |
| Pocatello | 4,477 | 60 | 68 | 25.45 | 30.10 | .00 | 28.5 | +0.4 | 49 | 5 | 37 | −6 | 1 | 20 | 29 | 25 | 20 | 68 | 0.94 | +0.1 | 13 | 8,103 | se. | 44 | sw. | 13 | 6 | 8 | 14 | 6.6 | 5.8 | 0.0 |
| Spokane | 1,929 | 101 | 110 | 27.93 | 30.03 | − .06 | 31.6 | +1.5 | 53 | 9 | 38 | 6 | 21 | 25 | 22 | 29 | 24 | 73 | 1.38 | −0.6 | 13 | 4,903 | sw. | 32 | sw. | 5 | 3 | 7 | 18 | 7.5 | 7.4 | T. |
| Walla Walla | 991 | 57 | 65 | 28.95 | 30.04 | − .07 | 38.7 | +2.3 | 67 | 9 | 46 | 16 | 1 | 31 | 27 | 34 | 27 | 67 | 1.30 | −0.3 | 13 | 4,440 | s. | 32 | sw. | 6 | 3 | 6 | 19 | 7.6 | 5.4 | 0.0 |
| *North Pacific Coast Region.* | | | | | | | **41.4** | **+0.1** | | | | | | | | | | **78** | **6.88** | **+1.6** | | | | | | | | | | **7.2** | | |
| North Head | 211 | 11 | 56 | 29.73 | 29.96 | −0.10 | 42.2 | +0.1 | 53 | 3 | 46 | 29 | 21 | 38 | 21 | 41 | 39 | 89 | 9.60 | +3.8 | 21 | 12,421 | se. | 72 | se. | 4 | 4 | 5 | 19 | 7.2 | 0.2 | 0.0 |
| North Yakima | 1,071 | 4 | | | | | 33.8 | | 60 | 5 | 44 | 10 | 2 | 24 | | | | | 0.73 | | 4 | | nw. | | | | 11 | 4 | 13 | | 4.1 | 0.0 |
| Port Angeles | 29 | 8 | 53 | 29.93 | 29.98 | | 38.4 | | 56 | 5 | 45 | 21 | 21 | 32 | 19 | | | | 2.90 | −0.1 | 12 | 4,449 | s. | 28 | nw. | 9 | 6 | 7 | 15 | 6.6 | 0.5 | 0.0 |
| Seattle | 125 | 215 | 250 | 29.87 | 30.00 | − .06 | 40.0 | −0.5 | 54 | 8 | 45 | 26 | 1 | 35 | 17 | 37 | 32 | 75 | 4.81 | +1.0 | 20 | 7,092 | se. | 40 | s. | 6 | 4 | 3 | 21 | 8.1 | 6.0 | 0.0 |
| Tacoma | 213 | 113 | 120 | 29.76 | 30.00 | − .06 | 40.4 | 0.0 | 58 | 4 | 46 | 25 | 1 | 35 | 25 | 38 | 33 | 76 | 5.75 | +0.6 | 18 | 4,566 | sw. | 33 | sw. | 9 | 3 | 3 | 23 | 8.2 | 7.3 | 0.0 |
| Tatoosh Island | 86 | 7 | 57 | 29.82 | 29.91 | − .09 | 41.0 | 0.0 | 50 | 3 | 44 | 31 | 1 | 38 | 14 | 39 | 36 | 82 | 13.40 | +4.6 | 21 | 15,916 | e. | 68 | s. | 4 | 6 | 5 | 17 | 6.9 | 4.9 | 0.0 |
| Medford | 1,425 | 4 | | | | | 42.0 | | 64 | 28 | 52 | 24 | 20 | 32 | 38 | | | | 2.64 | | 16 | | | | | | 4 | 11 | 13 | | 0.0 | 0.0 |
| Portland, Oreg | 153 | 68 | 106 | 29.85 | 30.01 | − .07 | 41.6 | +0.3 | 59 | 5 | 47 | 22 | 1 | 36 | 21 | 38 | 33 | 73 | 6.77 | +1.0 | 18 | 4,722 | se. | 27 | e. | 20 | 5 | 6 | 17 | 7.2 | 6.6 | 0.0 |
| Roseburg | 510 | 9 | 57 | 29.49 | 30.04 | − .06 | 43.4 | +0.8 | 68 | 9 | 52 | 25 | 20 | 35 | 36 | 40 | 36 | 76 | 4.96 | +0.4 | 19 | 2,041 | s. | 22 | sw. | 6 | 4 | 14 | 10 | 6.1 | 1.7 | 0.0 |
| *Middle Pacific Coast Region.* | | | | | | | **48.3** | **−0.7** | | | | | | | | | | **74** | **4.39** | **+0.1** | | | | | | | | | | **5.1** | | |
| Eureka | 62 | 73 | 89 | 30.01 | 30.08 | −0.03 | 47.0 | +0.2 | 64 | 3 | 54 | 32 | 25 | 40 | 25 | 44 | 41 | 79 | 6.29 | −0.7 | 16 | 5,859 | se. | 50 | sw. | 6 | 6 | 9 | 13 | 6.2 | 0.0 | 0.0 |
| Mount Tamalpais | 2,375 | 11 | 18 | 27.54 | 30.05 | − .05 | 42.5 | −3.1 | 62 | 9 | 47 | 31 | 18 | 38 | 19 | 39 | 35 | 78 | 5.02 | −0.7 | 15 | 15,364 | w. | 76 | nw. | 12 | 8 | 7 | 13 | 6.0 | 0.8 | 0.0 |
| Point Reyes Light | 490 | 7 | 18 | 29.51 | 30.03 | | 49.0 | −0.2 | 64 | 9 | 53 | 39 | 19 | 45 | 16 | | | | 4.03 | | 15 | 15,368 | nw. | 71 | nw. | 17 | 11 | 10 | 7 | 4.7 | 0.0 | 0.0 |
| Red Bluff | 332 | 50 | 56 | 29.70 | 30.07 | − .04 | 48.2 | −1.1 | 67 | 9 | 56 | 32 | 15 | 40 | 29 | 42 | 35 | 66 | 3.23 | −0.4 | 12 | 4,914 | nw. | 30 | nw. | 27 | 11 | 8 | 9 | 4.9 | 0.0 | 0.0 |
| Sacramento | 69 | 106 | 117 | 30.01 | 30.08 | − .01 | 49.3 | −0.9 | 67 | 10 | 58 | 33 | 15 | 41 | 28 | 45 | 40 | 71 | 3.36 | +0.2 | 14 | 5,825 | se. | 39 | nw. | 27 | 13 | 5 | 10 | 4.8 | 0.0 | 0.0 |
| San Francisco | 155 | 209 | 213 | 29.90 | 30.07 | − .03 | 51.8 | +0.5 | 67 | 10 | 58 | 40 | 19 | 46 | 20 | 47 | 43 | 74 | 5.79 | +2.1 | 15 | 5,788 | ne. | 37 | ne. | 27 | 14 | 8 | 6 | 4.3 | 0.0 | 0.0 |
| San Jose | 141 | 12 | 110 | 29.94 | 30.09 | | 50.0 | −0.6 | 70 | 9 | 60 | 30 | 16 | 40 | 34 | | | | 2.63 | +0.1 | 14 | 4,584 | se. | 27 | se. | 19 | 11 | 5 | 12 | 5.1 | 0.0 | 0.0 |
| *South Pacific Coast Region.* | | | | | | | **53.6** | **+1.0** | | | | | | | | | | **69** | **5.47** | **+3.0** | | | | | | | | | | **5.0** | | |
| Fresno | 327 | 89 | 98 | 29.72 | 30.09 | +0.01 | 51.4 | +2.2 | 71 | 10 | 61 | 33 | 15 | 42 | 31 | 45 | 38 | 63 | 4.59 | +3.3 | 9 | 4,236 | nw. | 28 | nw. | 7 | 8 | 11 | 9 | 5.4 | 0.0 | 0.0 |
| Los Angeles | 338 | 159 | 191 | 29.71 | 30.08 | + .02 | 56.0 | +1.9 | 80 | 9 | 64 | 39 | 19 | 48 | 28 | 48 | 41 | 66 | 6.14 | +3.2 | 11 | 4,560 | ne. | 29 | ne. | 21 | 12 | 6 | 10 | 4.8 | 0.0 | 0.0 |
| San Diego | 87 | 62 | 70 | 29.98 | 30.08 | + .02 | 55.1 | +0.5 | 74 | 8 | 62 | 40 | 2 | 48 | 27 | 50 | 45 | 72 | 1.52 | −0.4 | 10 | 4,579 | w. | 42 | s. | 17 | 13 | 10 | 5 | 4.2 | 0.0 | 0.0 |
| San Luis Obispo | 201 | 32 | 40 | 29.88 | 30.11 | .00 | 52.0 | −0.5 | 82 | 10 | 62 | 32 | 4 | 42 | 48 | 46 | 42 | 76 | 9.63 | +6.0 | 11 | 3,071 | nw. | 46 | se. | 20 | 12 | 3 | 13 | 5.6 | 0.0 | 0.0 |
| *West Indies.* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| San Juan, P. R | 82 | 8 | 54 | 29.97 | 30.05 | 0.00 | 74.2 | | 81 | 3 | 79 | 67 | 23 | 70 | 13 | | | | 7.84 | +5.3 | 22 | 11,574 | e. | 38 | e. | 14 | 12 | 14 | 2 | 4.1 | 0.0 | 0.0 |
| *Panama Canal.* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Balboa Heights | 118 | 7 | 97 | 29.75 | 29.87 | | 79.6 | | 90 | 19 | 88 | 67 | 24 | 71 | 21 | 71 | 70 | 81 | T. | −0.8 | 0 | 7,990 | n. | 32 | n. | 21 | 21 | 7 | 0 | 3.0 | 0.0 | 0.0 |
| Colon | 36 | 30 | 97 | 29.85 | 29.89 | | 78.7 | | 82 | 2 | 82 | 74 | 1 | 76 | 8 | 74 | 71 | 79 | 0.67 | −1.0 | 14 | 11,838 | n. | 30 | ne. | 21 | 2 | 23 | 3 | 5.3 | 0.0 | 0.0 |
| *Alaska.* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Juneau | 80 | 11 | 49 | | | | 27.4 | | 37 | 12 | 32 | 7 | 16 | 22 | 21 | 25 | 20 | 76 | 5.79 | | 18 | 2,925 | se. | 25 | se. | 7 | 5 | 6 | 17 | 7.0 | 59.4 | 28.6 |

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during February, 1918, at all stations furnished with self-registering gages.*

| Stations. | Date. | Total duration. | | Total amount of precipitation. | Excessive rate. | | Amount before excessive rate began. | Depths of precipitation (in inches) during periods of time indicated. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | From— | To— | | Began— | Ended— | | 5 min. | 10 min. | 15 min. | 20 min. | 25 min. | 30 min. | 35 min. | 40 min. | 45 min. | 50 min. | 60 min. | 80 min. | 100 min. | 120 min. |
| Abilene, Tex | 11 | | | 0.11 | | | | | | | | | | | | | | 0.04 | | | |
| Albany, N. Y | 28 | | | 0.46 | | | | | | | | | | | | | | * | | | |
| Alpena, Mich | 25 | | | 0.24 | | | | | | | | | | | | | | * | | | |
| Amarillo, Tex | 11 | | | 0.26 | | | | | | | | | | | | | | * | | | |
| Anniston, Ala | 20 | | | 0.45 | | | | | | | | | | | | | | 0.20 | | | |
| Asheville, N. C | 16 | | | 0.86 | | | | | | | | | | | | | | 0.33 | | | |
| Atlanta, Ga | 12 | | | 0.26 | | | | | | | | | | | | | | 0.24 | | | |
| Atlantic City, N. J | 20 | | | 0.29 | | | | | | | | | | | | | | 0.27 | | | |
| Augusta, Ga | 12 | | | 1.02 | | | | | | | | | | | | | | 0.27 | | | |
| Baker, Oreg | 12–13 | | | 0.14 | | | | | | | | | | | | | | * | | | |
| Baltimore, Md | 19 | | | 0.40 | | | | | | | | | | | | | | 0.18 | | | |
| Bentonville, Ark | 11 | | | 0.56 | | | | | | | | | | | | | | 0.26 | | | |
| Binghamton, N. Y | 28 | | | 0.71 | | | | | | | | | | | | | | * | | | |
| Birmingham, Ala | 12 | | | 0.25 | | | | | | | | | | | | | | 0.25 | | | |
| Bismarck, N. Dak | 13–14 | | | 0.16 | | | | | | | | | | | | | | * | | | |
| Block Island, R. I | 26 | | | 0.62 | | | | | | | | | | | | | | 0.31 | | | |
| Boise, Idaho | 16–17 | | | 0.32 | | | | | | | | | | | | | | * | | | |
| Boston, Mass | 26 | | | 0.82 | | | | | | | | | | | | | | 0.43 | | | |
| Buffalo, N. Y | 9 | | | 0.57 | | | | | | | | | | | | | | * | | | |
| Burlington, Vt | 25–26 | | | 0.50 | | | | | | | | | | | | | | * | | | |
| Cairo, Ill | 19 | | | 0.54 | | | | | | | | | | | | | | 0.46 | | | |
| Canton, N. Y | 12 | | | 0.96 | | | | | | | | | | | | | | * | | | |
| Charles City, Iowa | 13–14 | | | 0.13 | | | | | | | | | | | | | | * | | | |
| Charleston, S. C | 3 | | | 0.67 | | | | | | | | | | | | | | 0.27 | | | |
| Charlotte, N. C | 14 | 7:20 p. m. | D. N. p. m. | 0.73 | 9:26 p. m. | 9:55 p. m. | 0.08 | 0.14 | 0.40 | 0.46 | 0.50 | 0.51 | 0.65 | | | | | | | | |
| Chattanooga, Tenn | 20 | | | 0.56 | | | | | | | | | | | | | | 0.50 | | | |
| Cheyenne, Wyo | 27–28 | | | 0.45 | | | | | | | | | | | | | | * | | | |
| Chicago, Ill | 11–12 | | | 0.79 | | | | | | | | | | | | | | * | | | |
| Cincinnati, Ohio | 14 | | | 0.26 | | | | | | | | | | | | | | 0.26 | | | |
| Cleveland, Ohio | 28 | | | 0.27 | | | | | | | | | | | | | | * | | | |
| Columbia, Mo | 11–12 | | | 0.61 | | | | | | | | | | | | | | * | | | |
| Columbia, S. C | 2 | | | 0.56 | | | | | | | | | | | | | | 0.17 | | | |
| Columbus, Ohio | 19 | | | 1.30 | | | | | | | | | | | | | | 0.33 | | | |
| Concord, N. H | 16–71 | | | 0.71 | | | | | | | | | | | | | | * | | | |
| Concordia, Kans | 27–28 | | | 0.46 | | | | | | | | | | | | | | * | | | |
| Corpus Christi, Tex | 9 | | | 0.31 | | | | | | | | | | | | | | 0.18 | | | |
| Dallas, Tex | 28 | | | 0.53 | | | | | | | | | | | | | | 0.24 | | | |
| Davenport, Iowa | 27–28 | | | 0.51 | | | | | | | | | | | | | | * | | | |
| Dayton, Ohio | 25 | | | 1.14 | | | | | | | | | | | | | | 0.61 | | | |
| Del Rio, Tex | 10–11 | | | 0.04 | | | | | | | | | | | | | | * | | | |
| Denver, Colo | 27 | | | 0.70 | | | | | | | | | | | | | | * | | | |
| Des Moines, Iowa | 8 | | | 0.81 | | | | | | | | | | | | | | * | | | |
| Detroit, Mich | 25–26 | | | 0.93 | | | | | | | | | | | | | | * | | | |
| Devils Lake, N. Dak | 7 | | | 0.08 | | | | | | | | | | | | | | * | | | |
| Dodge City, Kans | 27 | | | 0.24 | | | | | | | | | | | | | | * | | | |
| Drexel, Nebr | 15–16 | | | 0.34 | | | | | | | | | | | | | | * | | | |
| Dubuque, Iowa | 8 | | | 0.62 | | | | | | | | | | | | | | * | | | |
| Duluth, Minn | 7–8 | | | 0.09 | | | | | | | | | | | | | | * | | | |
| Eastport, Me | 19 | | | 0.57 | | | | | | | | | | | | | | 0.24 | | | |
| Elkins, W. Va | 25 | | | 1.17 | | | | | | | | | | | | | | 0.57 | | | |
| Ellendale, N. Dak | 13–14 | | | 0.46 | | | | | | | | | | | | | | * | | | |
| El Paso, Tex | 10 | | | 0.01 | | | | | | | | | | | | | | T. | | | |
| Erie, Pa | 8–9 | | | 0.27 | | | | | | | | | | | | | | * | | | |
| Escanaba, Mich | 14–15 | | | 1.10 | | | | | | | | | | | | | | * | | | |
| Eureka, Cal | 17 | | | 0.56 | | | | | | | | | | | | | | 0.21 | | | |
| Evansville, Ind | 9 | | | 0.08 | | | | | | | | | | | | | | 0.08 | | | |
| Flagstaff, Ariz | 22 | | | 0.58 | | | | | | | | | | | | | | * | | | |
| Fort Smith, Ark | 11 | | | 0.47 | | | | | | | | | | | | | | 0.34 | | | |
| Fort Wayne, Ind | 11–12 | | | 0.81 | | | | | | | | | | | | | | * | | | |
| Fort Worth, Tex | 11 | | | 0.01 | | | | | | | | | | | | | | T. | | | |
| Fresno, Cal | 20 | | | 1.41 | | | | | | | | | | | | | | 0.21 | | | |
| Galveston, Tex | 17 | | | 0.58 | | | | | | | | | | | | | | 0.34 | | | |
| Grand Haven, Mich | 11–12 | | | 0.83 | | | | | | | | | | | | | | * | | | |
| Grand Junction, Colo | 27 | | | 0.24 | | | | | | | | | | | | | | * | | | |
| Grand Rapids, Mich | 11–12 | | | 1.60 | | | | | | | | | | | | | | * | | | |
| Green Bay, Wis | 14 | | | 0.85 | | | | | | | | | | | | | | * | | | |
| Greenville, S. C | 14 | 5:20 p. m. | 8:30 p. m. | 1.33 | 6:47 p. m. | 8:10 p. m. | 0.07 | 0.10 | 0.22 | 0.38 | 0.42 | 0.42 | 0.42 | 0.42 | 0.47 | 0.63 | 0.70 | 0.77 | 1.06 | 1.26 | |
| Hannibal, Mo | 12 | | | 0.44 | | | | | | | | | | | | | | 0.25 | | | |
| Harrisburg, Pa | 25 | | | 0.79 | | | | | | | | | | | | | | 0.35 | | | |
| Hartford, Conn | 26 | | | 0.75 | | | | | | | | | | | | | | 0.34 | | | |
| Hatteras, N. C | 22 | | | 0.73 | | | | | | | | | | | | | | 0.20 | | | |
| Havre, Mont | 13–14 | | | 0.14 | | | | | | | | | | | | | | * | | | |
| Helena, Mont | 17–18 | | | 0.16 | | | | | | | | | | | | | | * | | | |
| Houghton, Mich | 25 | | | 0.16 | | | | | | | | | | | | | | * | | | |
| Houston, Tex | 17 | | | 0.62 | | | | | | | | | | | | | | 0.33 | | | |
| Huron, S. Dak | 13–14 | | | 0.61 | | | | | | | | | | | | | | * | | | |
| Independence, Cal | 20–21 | | | 0.62 | | | | | | | | | | | | | | * | | | |
| Indianapolis, Ind | 28 | | | 0.80 | | | | | | | | | | | | | | 0.33 | | | |
| Iola, Kans | 27 | | | 0.56 | | | | | | | | | | | | | | 0.39 | | | |
| Jacksonville, Fla | 22 | | | 0.10 | | | | | | | | | | | | | | 0.10 | | | |
| Kalispell, Mont | 11 | | | 0.28 | | | | | | | | | | | | | | * | | | |
| Kansas City, Mo | 27 | | | 0.92 | | | | | | | | | | | | | | 0.39 | | | |
| Keokuk, Iowa | 27–28 | | | 0.75 | | | | | | | | | | | | | | * | | | |
| Key West, Fla | 21–22 | | | 0.10 | | | | | | | | | | | | | | 0.03 | | | |
| Knoxville, Tenn | 20 | | | 0.81 | | | | | | | | | | | | | | 0.65 | | | |
| La Crosse, Wis | 13–14 | | | 0.43 | | | | | | | | | | | | | | * | | | |
| Lander, Wyo | 27 | | | 0.44 | | | | | | | | | | | | | | * | | | |
| Lansing, Mich | 11–12 | | | 1.17 | | | | | | | | | | | | | | * | | | |
| Lewiston, Idaho | 17 | | | 0.14 | | | | | | | | | | | | | | 0.08 | | | |
| Lexington, Ky | 9 | | | 0.29 | | | | | | | | | | | | | | 0.26 | | | |
| Lincoln, Nebr | 27–28 | | | 0.46 | | | | | | | | | | | | | | * | | | |
| Little Rock, Ark | 19 | | | 0.50 | | | | | | | | | | | | | | 0.24 | | | |
| Los Angeles, Cal | 17 | | | 1.02 | | | | | | | | | | | | | | 0.50 | | | |
| Louisville, Ky | 19 | | | 1.09 | | | | | | | | | | | | | | 0.62 | | | |
| Ludington, Mich | 8 | | | 0.41 | | | | | | | | | | | | | | * | | | |
| Lynchburg, Va | 19 | | | 0.18 | | | | | | | | | | | | | | 0.12 | | | |
| Macon, Ga | 20 | | | 0.35 | | | | | | | | | | | | | | 0.33 | | | |
| Madison, Wis | 8 | | | 0.48 | | | | | | | | | | | | | | * | | | |
| Marquette, Mich | 14–15 | | | 1.15 | | | | | | | | | | | | | | * | | | |

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during February, 1918, at all stations furnished with self-registering gages*—Continued.

| Stations. | Date. | Total duration. | | Total amount of precipitation. | Excessive rate. | | Amount before excessive rate began. | Depths of precipitation (in inches) during periods of time indicated. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | From— | To— | | Began— | Ended— | | 5 min. | 10 min. | 15 min. | 20 min. | 25 min. | 30 min. | 35 min. | 40 min. | 45 min. | 50 min. | 60 min. | 80 min. | 100 min. | 120 min. |
| Memphis, Tenn. | 19 | 10:55 a. m. | 5:55 p. m. | 1.64 | 3:43 p. m. | 3:59 p. m. | 0.28 | 0.32 | 0.34 | 0.52 | 0.60 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Meridian, Miss. | 16 | | | 0.87 | | | | | | | | | | | | | | 0.31 | ..... | ..... | ..... |
| Miami, Fla. | 17 | D. N. a. m. | 7:25 a. m. | 1.73 | 4:50 a. m. | 5:40 a. m. | 0.02 | 0.08 | 0.17 | 0.26 | 0.32 | 0.35 | 0.40 | 0.47 | 0.51 | 0.63 | 0.70 | ..... | ..... | ..... | ..... |
| | | | | | 5:40 a. m. | 6:30 a. m. | ..... | 0.76 | 0.82 | 0.96 | 1.01 | 1.06 | 1.10 | 1.10 | 1.12 | 1.20 | 1.25 | ..... | ..... | ..... | ..... |
| | | | | | 6:30 a. m. | 7:01 a. m. | ..... | 1.30 | 1.33 | 1.40 | 1.46 | 1.57 | 1.67 | 1.68 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Milwaukee, Wis. | 8 | | | 0.90 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Minneapolis, Minn. | 13–14 | | | 0.35 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Mobile, Ala. | 20 | | | 0.59 | | | | | | | | | | | | | | 0.47 | ..... | ..... | ..... |
| Modena, Utah | 22–23 | | | 0.42 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Montgomery, Ala. | 20 | | | 0.39 | | | | | | | | | | | | | | 0.17 | ..... | ..... | ..... |
| Moorhead, Minn. | 7 | | | 0.11 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Mount Tamalpais, Cal. | 16 | | | 0.71 | | | | | | | | | | | | | | 0.36 | ..... | ..... | ..... |
| Nantucket, Mass. | 20 | | | 0.70 | | | | | | | | | | | | | | 0.37 | ..... | ..... | ..... |
| Nashville, Tenn. | 19 | | | 0.55 | | | | | | | | | | | | | | 0.32 | ..... | ..... | ..... |
| New Haven, Conn. | 26 | | | 1.25 | | | | | | | | | | | | | | 0.65 | ..... | ..... | ..... |
| New Orleans, La. | 16 | 6:04 a. m. | 6:38 a. m. | 0.56 | 6:10 a. m. | 6:26 a. m. | 0.02 | 0.09 | 0.25 | 0.50 | 0.52 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| New York, N. Y. | 26 | | | 0.58 | | | | | | | | | | | | | | 0.24 | ..... | ..... | ..... |
| Norfolk, Va. | 3 | | | 0.10 | | | | | | | | | | | | | | 0.03 | ..... | ..... | ..... |
| Northfield, Vt. | 25–26 | | | 0.81 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| North Head, Wash. | 4 | | | 1.78 | | | | | | | | | | | | | | 0.47 | ..... | ..... | ..... |
| North Platte, Nebr. | 13 | | | 0.09 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Oklahoma, Okla. | 27 | | | 0.03 | | | | | | | | | | | | | | 0.03 | ..... | ..... | ..... |
| Omaha, Nebr. | 15–16 | | | 0.48 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Oswego, N. Y. | 12 | | | 0.48 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Palestine, Tex. | 28 | | | 0.49 | | | | | | | | | | | | | | 0.24 | ..... | ..... | ..... |
| Parkersburg, W. Va. | 19 | | | 1.16 | | | | | | | | | | | | | | 0.35 | ..... | ..... | ..... |
| Pensacola, Fla. | 3 | 2:25 a. m. | 5:15 a. m. | 0.67 | 4:26 a. m. | 4:40 a. m. | 0.05 | 0.32 | 0.46 | 0.55 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Peoria, Ill. | 28 | | | 0.49 | | | | | | | | | | | | | | 0.17 | ..... | ..... | ..... |
| Philadelphia, Pa. | 19 | | | 0.67 | | | | | | | | | | | | | | 0.30 | ..... | ..... | ..... |
| Phoenix, Ariz. | 18 | | | 0.13 | | | | | | | | | | | | | | 0.08 | ..... | ..... | ..... |
| Pierre, S. Dak. | 13–14 | | | 0.59 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Pittsburgh, Pa. | 19–20 | | | 0.79 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Pocatello, Idaho | 6 | | | 0.18 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Point Reyes Light, Cal. | 19 | | | 0.55 | | | | | | | | | | | | | | 0.24 | ..... | ..... | ..... |
| Port Angeles, Wash. | 4 | | | 0.96 | | | | | | | | | | | | | | 0.34 | ..... | ..... | ..... |
| Port Huron, Mich. | 25 | | | 0.67 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Portland, Me. | 9 | | | 0.58 | | | | | | | | | | | | | | 0.16 | ..... | ..... | ..... |
| Portland, Oreg. | 4 | | | 1.03 | | | | | | | | | | | | | | 0.27 | ..... | ..... | ..... |
| Providence, R. I. | 19–20 | | | 1.15 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Pueblo, Colo. | 27 | | | 0.70 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Raleigh, N. C. | 20 | | | 0.21 | | | | | | | | | | | | | | 0.20 | ..... | ..... | ..... |
| Rapid City, S. Dak. | 13–14 | | | 0.41 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Reading, Pa. | 19 | | | 0.83 | | | | | | | | | | | | | | 0.17 | ..... | ..... | ..... |
| Red Bluff, Cal. | 16 | | | 0.55 | | | | | | | | | | | | | | 0.18 | ..... | ..... | ..... |
| Reno, Nev. | 21–22 | | | 0.55 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Richmond, Va. | 15 | | | 0.42 | | | | | | | | | | | | | | 0.42 | ..... | ..... | ..... |
| Rochester, N. Y. | 9 | | | 0.54 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Roseburg, Oreg. | 6 | | | 0.70 | | | | | | | | | | | | | | 0.22 | ..... | ..... | ..... |
| Roswell, N. Mex. | 10 | | | 0.02 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Sacramento, Cal. | 6 | | | 0.53 | | | | | | | | | | | | | | 0.23 | ..... | ..... | ..... |
| Saginaw, Mich. | 11–12 | | | 1.01 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| St. Joseph, Mo. | 27–28 | | | 1.04 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| St. Louis, Mo. | 12 | | | 1.06 | | | | | | | | | | | | | | 0.38 | ..... | ..... | ..... |
| St. Paul, Minn. | 13–14 | | | 0.45 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Salt Lake City, Utah | 7 | | | 0.45 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| San Antonio, Tex. | 16 | | | 0.31 | | | | | | | | | | | | | | 0.27 | ..... | ..... | ..... |
| San Diego, Cal. | 22 | | | 0.53 | | | | | | | | | | | | | | 0.29 | ..... | ..... | ..... |
| Sand Key, Fla. | 19 | | | 0.06 | | | | | | | | | | | | | | 0.06 | ..... | ..... | ..... |
| Sandusky, Ohio | 19 | | | 0.42 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Sandy Hook, N. J. | 19–20 | | | 0.84 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| San Francisco, Cal. | 23 | | | 1.43 | | | | | | | | | | | | | | 0.47 | ..... | ..... | ..... |
| San Jose, Cal. | 19 | | | 0.43 | | | | | | | | | | | | | | 0.24 | ..... | ..... | ..... |
| San Luis Obispo, Cal. | 20 | | | 2.38 | | | | | | | | | | | | | | 0.66 | ..... | ..... | ..... |
| Santa Fe, N. Mex. | 26–27 | | | 0.68 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Sault Ste. Marie, Mich. | 25 | | | 0.45 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Savannah, Ga. | 3 | | | 0.25 | | | | | | | | | | | | | | 0.15 | ..... | ..... | ..... |
| Scranton, Pa. | 19 | | | 0.58 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Seattle, Wash. | 16 | | | 0.43 | | | | | | | | | | | | | | 0.16 | ..... | ..... | ..... |
| Sheridan, Wyo. | 24 | | | 0.07 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Shreveport, La. | 16 | | | 0.07 | | | | | | | | | | | | | | 0.05 | ..... | ..... | ..... |
| Sioux City, Iowa | 14 | | | 0.62 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Spokane, Wash. | 6 | | | 0.40 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Springfield, Ill. | 12 | | | 0.98 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Springfield, Mo. | 11–12 | | | 0.49 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Syracuse, N. Y. | 20–21 | | | 0.44 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Tacoma, Wash. | 4 | | | 1.07 | | | | | | | | | | | | | | 0.24 | ..... | ..... | ..... |
| Tampa, Fla. | 18 | | | 0.04 | | | | | | | | | | | | | | 0.04 | ..... | ..... | ..... |
| Tatoosh Island, Wash. | 5 | | | 0.99 | | | | | | | | | | | | | | 0.33 | ..... | ..... | ..... |
| Taylor, Tex. | 17 | | | 1.81 | | | | | | | | | | | | | | 0.21 | ..... | ..... | ..... |
| Terre Haute, Ind. | 12 | | | 0.75 | | | | | | | | | | | | | | 0.25 | ..... | ..... | ..... |
| Thomasville, Ga. | 3 | 7:01 a. m. | 12:35 p. m. | 1.75 | 11:18 a. m. | 11:34 a. m. | 0.80 | 0.19 | 0.69 | 0.83 | 0.88 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Toledo, Ohio | 19 | | | 0.59 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Tonopah, Nev. | 17–18 | | | 0.23 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Topeka, Kans. | 28 | | | 0.49 | | | | | | | | | | | | | | 0.39 | ..... | ..... | ..... |
| Trenton, N. J. | 19 | | | 0.65 | | | | | | | | | | | | | | 0.25 | ..... | ..... | ..... |
| Valentine, Nebr. | 15 | | | 0.11 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Vicksburg, Miss. | 16 | 6:58 a. m. | 3:10 p. m. | 1.72 | 7:47 a. m. | 8:37 a. m. | 0.11 | 0.12 | 0.22 | 0.29 | 0.38 | 0.42 | 0.44 | 0.50 | 0.55 | 0.65 | 0.81 | ..... | ..... | ..... | ..... |
| Walla Walla, Wash. | 23 | | | 0.31 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Washington, D. C. | 26 | | | 0.34 | | | | | | | | | | | | | | 0.22 | ..... | ..... | ..... |
| Wausau, Wis. | 14 | | | 0.57 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Wichita, Kans. | 27 | | | 1.93 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Williston, N. Dak. | 17–18 | | | 0.10 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Wilmington, N. C. | 20 | | | 0.53 | | | | | | | | | | | | | | 0.51 | ..... | ..... | ..... |
| Winnemucca, Nev. | 22 | | | 0.28 | | | | | | | | | | | | | | 0.20 | ..... | ..... | ..... |
| Wytheville, Va. | 20 | | | 0.18 | | | | | | | | | | | | | | 0.15 | ..... | ..... | ..... |
| Yankton, S. Dak. | 14 | | | 0.68 | | | | | | | | | | | | | | * | ..... | ..... | ..... |
| Yellowstone Park, Wyo. | 12–13 | | | 0.69 | | | | | | | | | | | | | | * | ..... | ..... | ..... |

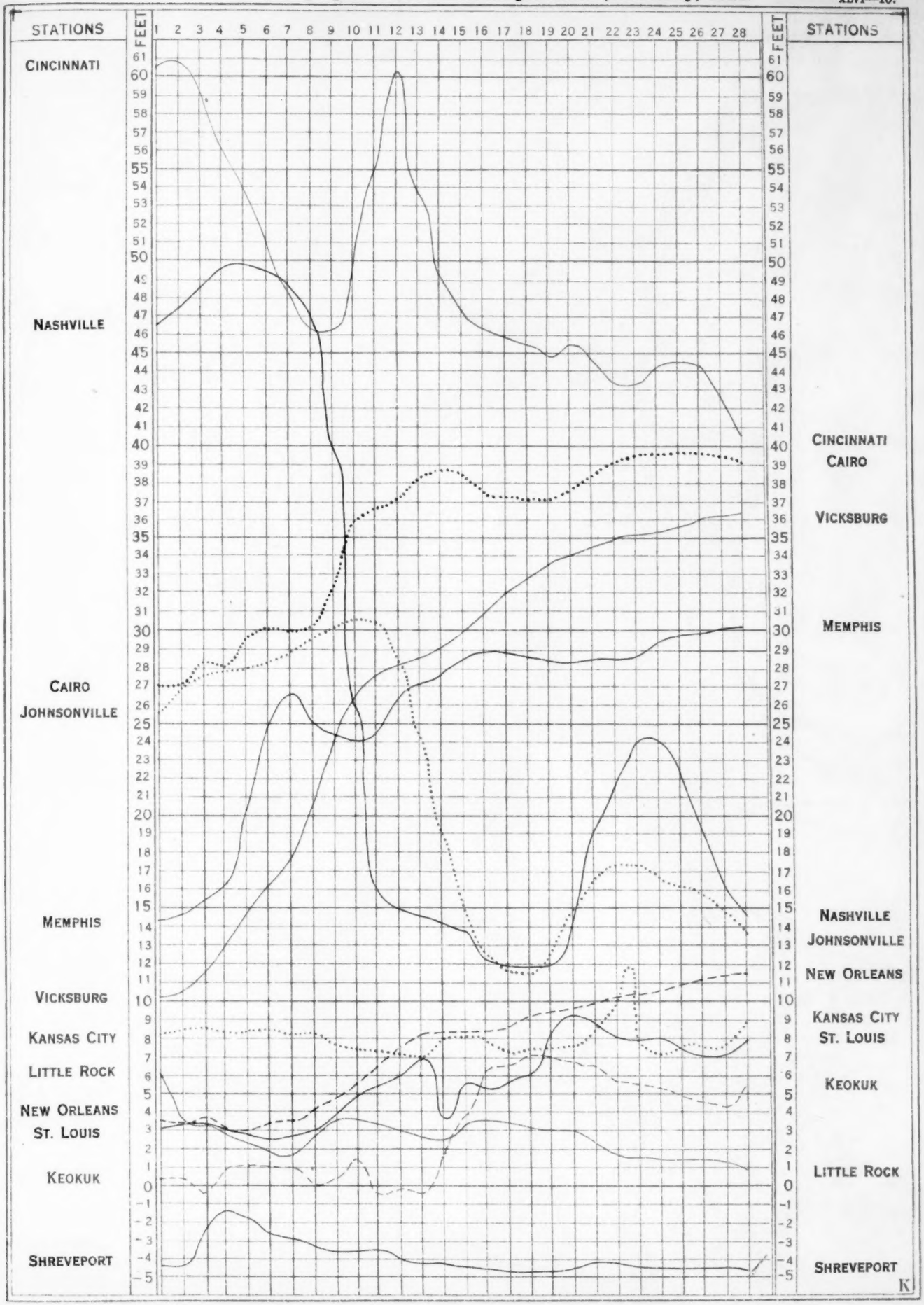
* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE III—*Data furnished by the Canadian Meteorological Service, February, 1918.*

| Stations. | Altitude above M. S. L.* Jan. 1, 1916. | Pressure. | | | Temperature. | | | | | | Precipitation. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Station reduced to mean of 24 hours. | Sea level reduced to mean of 24 hours. | Departure from normal. | Mean max.+ mean min.÷2. | Departure from normal. | Mean maximum. | Mean minimum. | Highest. | Lowest. | Total. | Departure from normal. | Total snowfall. |
| | *Feet.* | *Inches.* | *Inches.* | *Inches.* | °*F.* | °*F.* | °*F.* | °*F.* | °*F.* | °*F.* | *Inches.* | *Inches.* | *Inches.* |
| St. Johns, N. F. | 125 | 29.66 | 29.80 | −0.03 | 21.3 | −0.7 | 29.2 | 13.4 | 48 | − 2 | 4.57 | −0.34 | 17.0 |
| Sydney, C. B. I. | 48 | 29.90 | 29.94 | + .02 | 16.9 | −2.4 | 29.2 | 4.7 | 48 | −12 | 5.95 | +1.86 | 39.5 |
| Halifax, N. S. | 88 | 29.86 | 29.97 | + .02 | 19.9 | −2.5 | 30.5 | 9.3 | 49 | −13 | 6.12 | +0.96 | 42.8 |
| Yarmouth, N. S. | 65 | 29.89 | 29.96 | − .03 | 23.2 | −2.6 | 31.5 | 15.0 | 49 | − 3 | 4.08 | −0.66 | 18.4 |
| Charlottetown, P. E. I. | 38 | 29.89 | 29.93 | − .02 | 13.0 | −4.6 | 22.4 | 3.6 | 45 | −16 | 3.09 | +0.03 | 24.3 |
| Chatham, N. B. | 28 | 29.92 | 29.95 | −0.01 | 9.6 | −2.9 | 21.6 | − 2.4 | 48 | −24 | 2.98 | −0.18 | 21.7 |
| Father Point, Que. | 20 | 29.93 | 29.96 | − .02 | 5.2 | −6.3 | 14.8 | − 4.3 | 42 | −24 | 1.77 | −0.44 | 16.7 |
| Quebec, Que. | 296 | 29.62 | 29.96 | − .03 | 7.5 | −4.3 | 16.9 | − 1.9 | 44 | −27 | 3.96 | +0.69 | 31.3 |
| Montreal, Que. | 187 | 29.76 | 29.99 | − .03 | 12.0 | −2.5 | 21.2 | 2.9 | 46 | −24 | 4.99 | +1.92 | 34.5 |
| Stonecliffe, Ont. | 489 | 29.36 | 30.00 | − .01 | 6.2 | −3.7 | 18.0 | − 5.6 | 42 | −32 | 1.78 | −0.22 | 16.6 |
| Ottawa, Ont. | 236 | 29.72 | 30.00 | −0.02 | 10.0 | −1.7 | 21.5 | − 1.5 | 44 | −28 | 3.61 | −0.92 | 24.8 |
| Kingston, Ont. | 285 | 29.68 | 30.02 | − .02 | 15.6 | −2.2 | 25.8 | 5.4 | 46 | −27 | 3.03 | +0.49 | 10.5 |
| Toronto, Ont. | 379 | 29.58 | 30.01 | − .03 | 21.1 | −0.4 | 30.6 | 11.6 | 49 | −20 | 4.05 | +1.44 | 11.6 |
| White River, Ont. | 1,244 | 28.54 | 29.93 | − .09 | − 3.2 | −3.4 | 11.7 | −18.1 | 35 | −51 | 1.28 | −0.24 | 12.8 |
| Port Stanley, Ont. | 392 | 29.36 | 30.03 | − .03 | 20.9 | −1.9 | 30.3 | 11.6 | 46 | −23 | 3.50 | +0.29 | 14.4 |
| Southampton, Ont. | 656 | 29.23 | ..... | ..... | 16.1 | −3.8 | 27.1 | 5.2 | 43 | −28 | 3.33 | +0.43 | 17.4 |
| Parry Sound, Ont. | 688 | 29.26 | 30.00 | −0.01 | 12.9 | −1.4 | 25.4 | 0.4 | 42 | −37 | 1.58 | +1.34 | 9.2 |
| Port Arthur, Ont. | 644 | 29.24 | 29.98 | − .07 | 7.3 | +0.9 | 18.6 | − 3.9 | 44 | −26 | 0.68 | −0.22 | 6.8 |
| Winnipeg, Man. | 760 | 29.19 | 30.09 | − .01 | 1.9 | +3.5 | 12.6 | − 8.7 | 41 | −30 | 0.59 | −0.39 | 5.9 |
| Minnedosa, Man. | 1,690 | 28.69 | 30.02 | − .07 | 0.9 | +3.6 | 13.9 | −12.0 | 36 | −38 | 0.71 | +0.10 | 7.1 |
| Qu'Appelle, Sask. | 2,115 | 27.61 | 29.97 | −0.11 | 6.0 | +6.6 | 16.8 | 4.7 | 41 | −38 | 0.58 | −0.15 | 5.8 |
| Medicine Hat, Alberta. | 2,144 | 27.57 | 29.95 | − .10 | 15.8 | +4.6 | 25.9 | 5.8 | 46 | −44 | 0.84 | +0.17 | 8.4 |
| Swift Current, Sask. | 2,392 | 27.26 | 29.96 | − .11 | 12.6 | +4.6 | 22.9 | 2.3 | 45 | −35 | 0.92 | +0.18 | 9.2 |
| Calgary, Alberta. | 3,428 | 26.26 | 29.94 | − .05 | 16.5 | +3.0 | 31.0 | 1.9 | 55 | −28 | 0.60 | −0.03 | 6.0 |
| Banff, Alberta. | 4,521 | 25.19 | 29.96 | − .02 | 14.0 | −5.2 | 24.5 | 3.8 | 37 | −37 | 1.95 | +1.03 | 19.4 |
| Edmonton, Alberta. | 2,150 | 27.52 | 29.90 | −0.02 | 12.2 | +3.9 | 23.3 | 1.2 | 53 | −33 | 0.35 | −0.32 | 3.5 |
| Prince Albert, Sask. | 1,450 | 28.35 | 29.99 | − .10 | 2.1 | +5.1 | 15.1 | −10.9 | 44 | −46 | 0.14 | −0.54 | 1.4 |
| Battleford, Sask. | 1,592 | 28.15 | 30.00 | − .09 | 4.0 | +3.9 | 15.4 | − 7.5 | 42 | −42 | 0.33 | −0.04 | 3.3 |
| Kamloops, B. C. | 1,262 | 28.68 | 30.01 | + .05 | 25.7 | −2.6 | 33.3 | 18.2 | 53 | − 2 | 0.43 | −0.36 | 3.7 |
| Victoria, B. C. | 230 | 29.69 | 29.95 | − .05 | 40.0 | +0.5 | 43.8 | 35.2 | 52 | 25 | 3.87 | −0.23 | 1.4 |
| Barkerville, B. C. | 4,180 | 25.48 | 29.91 | 0.00 | 16.4 | −2.5 | 25.4 | 7.5 | 36 | −20 | 2.85 | −0.21 | 28.5 |
| Hamilton, Bermuda. | 151 | 30.08 | 30.24 | + .13 | 62.4 | +0.9 | 67.6 | 57.3 | 73 | 48 | 1.34 | −3.10 | 0.0 |

*See explanation of tables, this REVIEW for January, 1918, p. 48.

## Chart I. Hydrographs of Several Principal Rivers, February, 1918.

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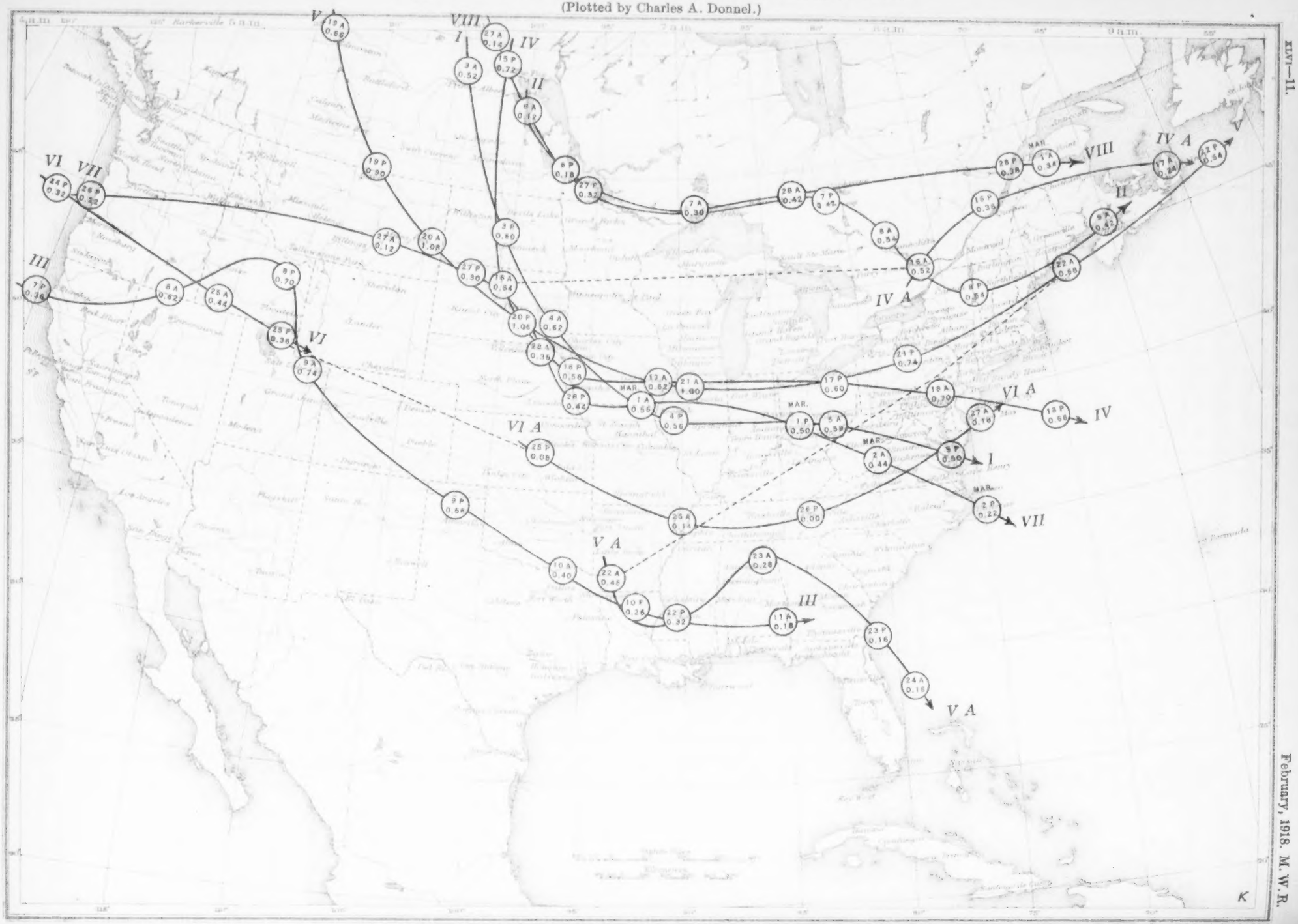
## Chart II. Tracks of Centers of High Areas, February, 1918.

(Plotted by Charles A. Donnel.)








## Chart III. Tracks of Centers of Low Areas, February, 1918.

## Chart III. Tracks of Centers of Low Areas, February, 1918.

(Plotted by Charles A. Donnel.)

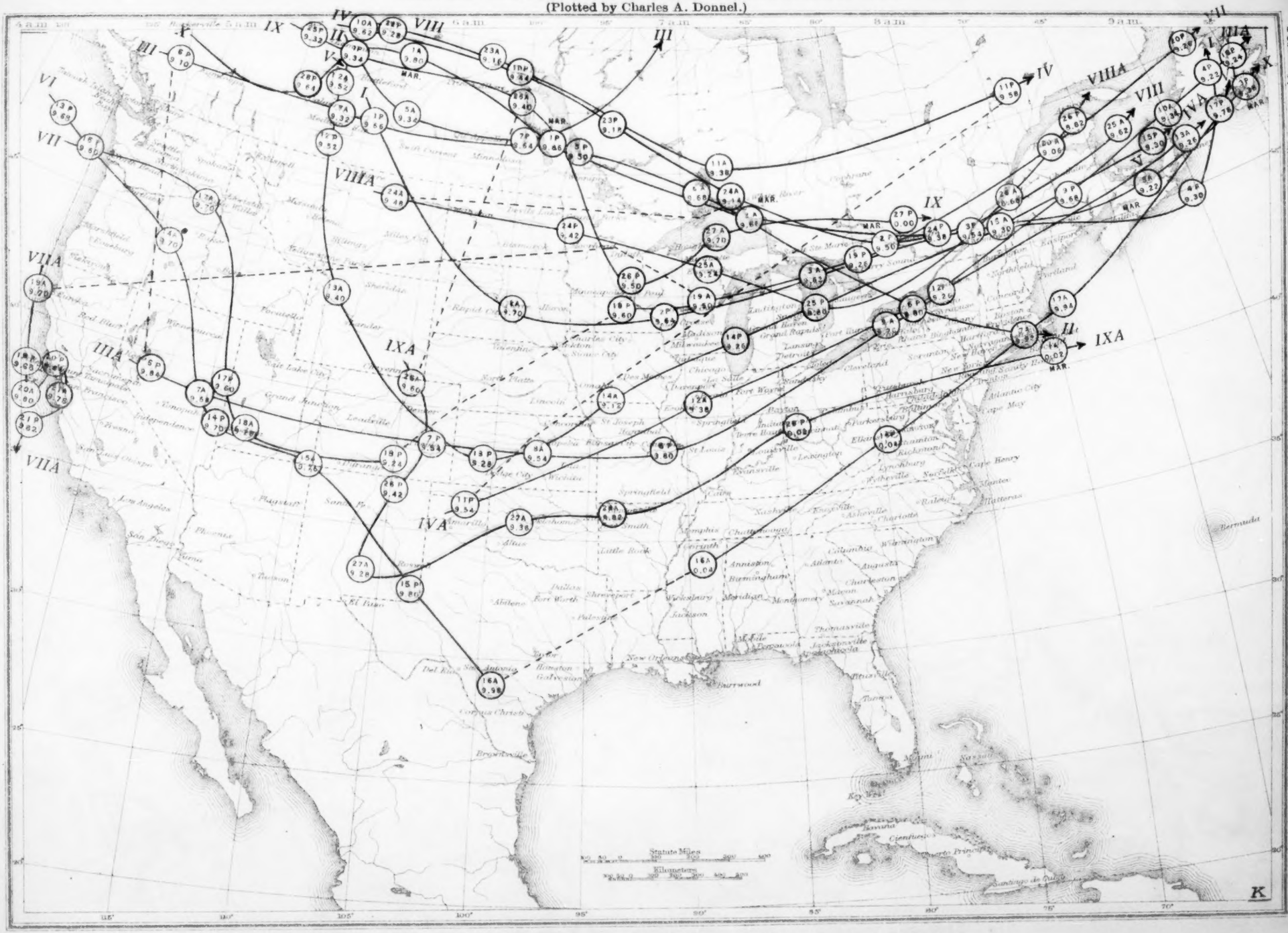


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, February, 1918.

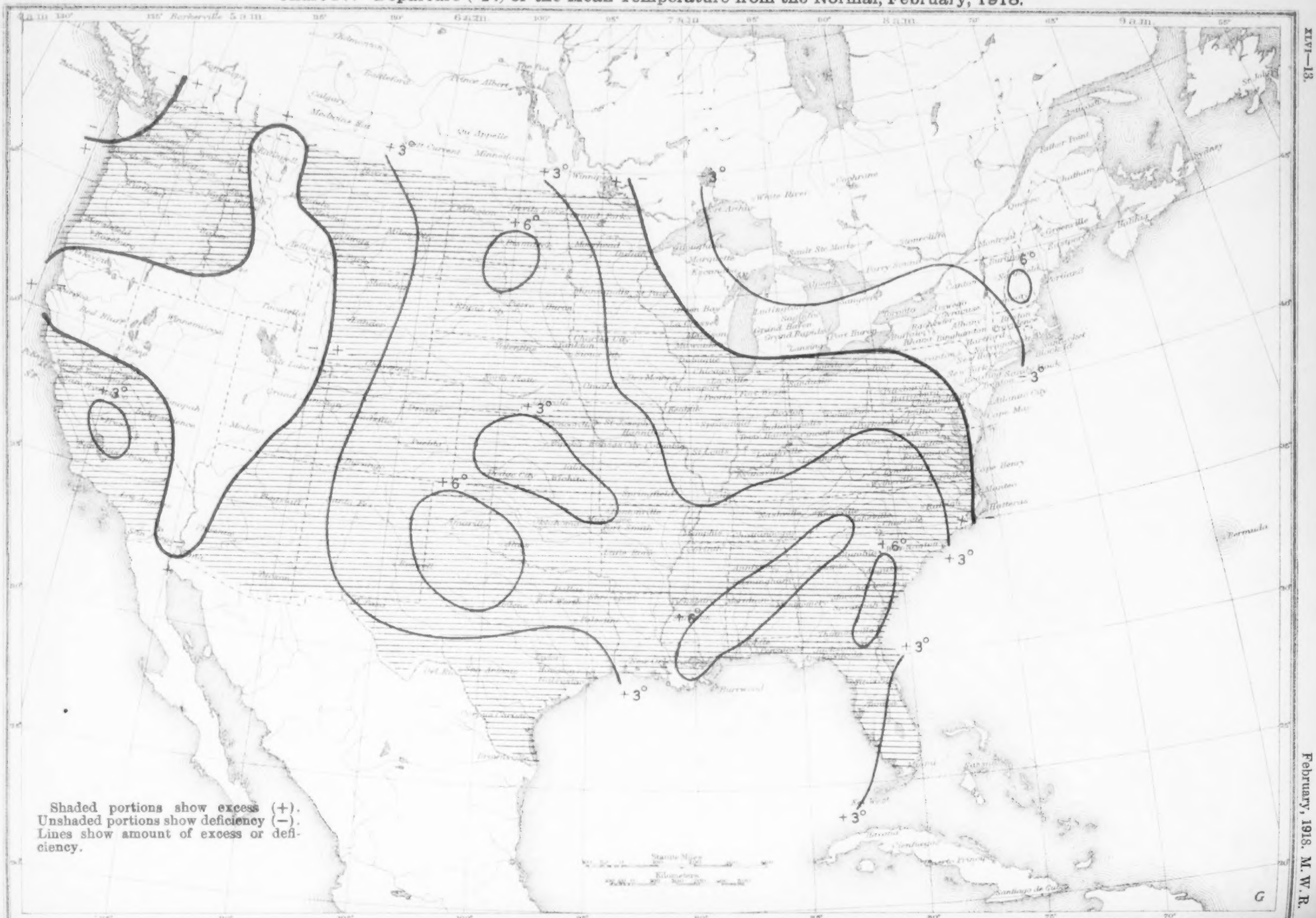
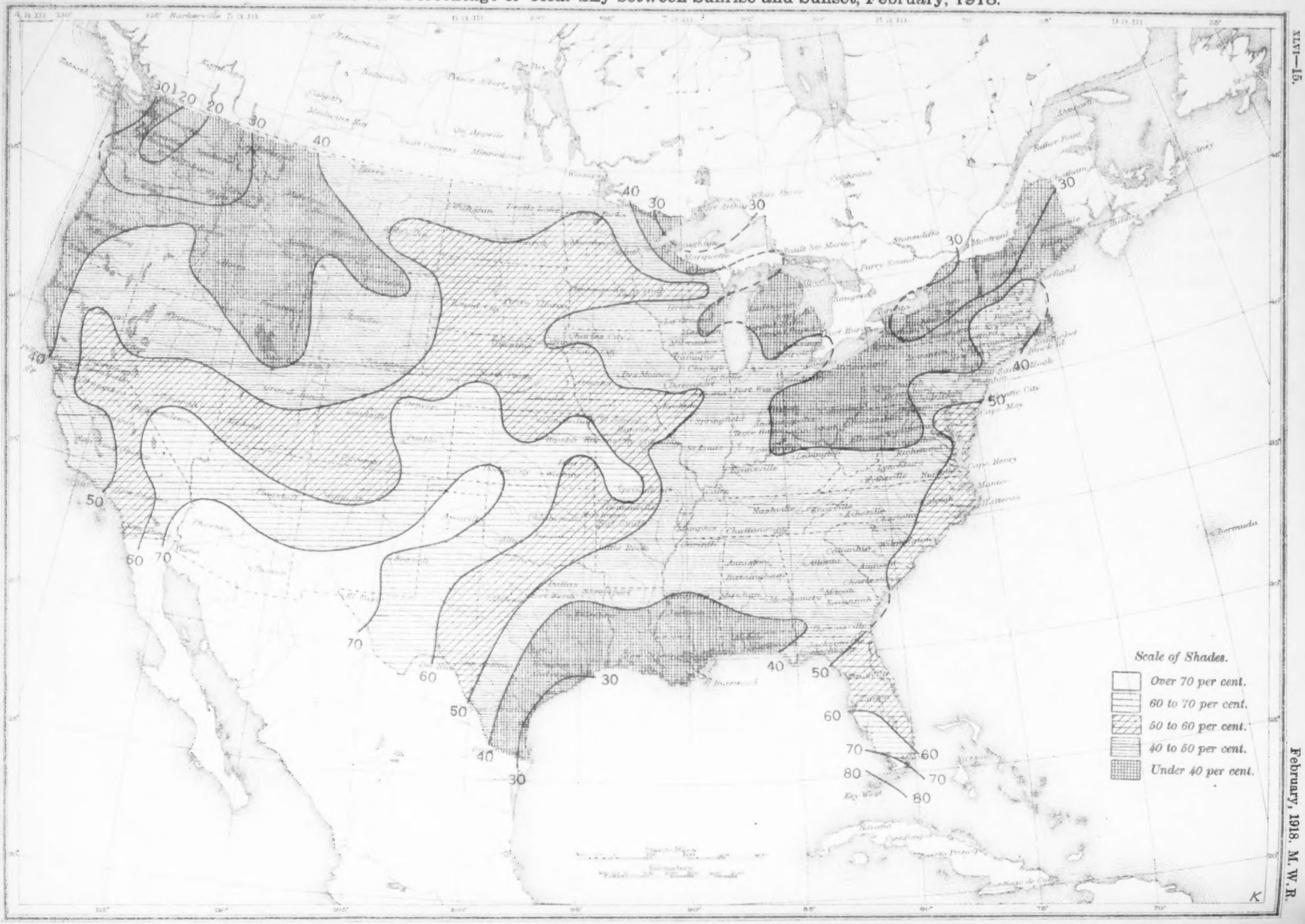


Chart V. Total Precipitation, February, 1918.

## Chart VI. Percentage of Clear Sky between Sunrise and Sunset, February, 1918.






## Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, February, 1918.

## Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, February, 1918.

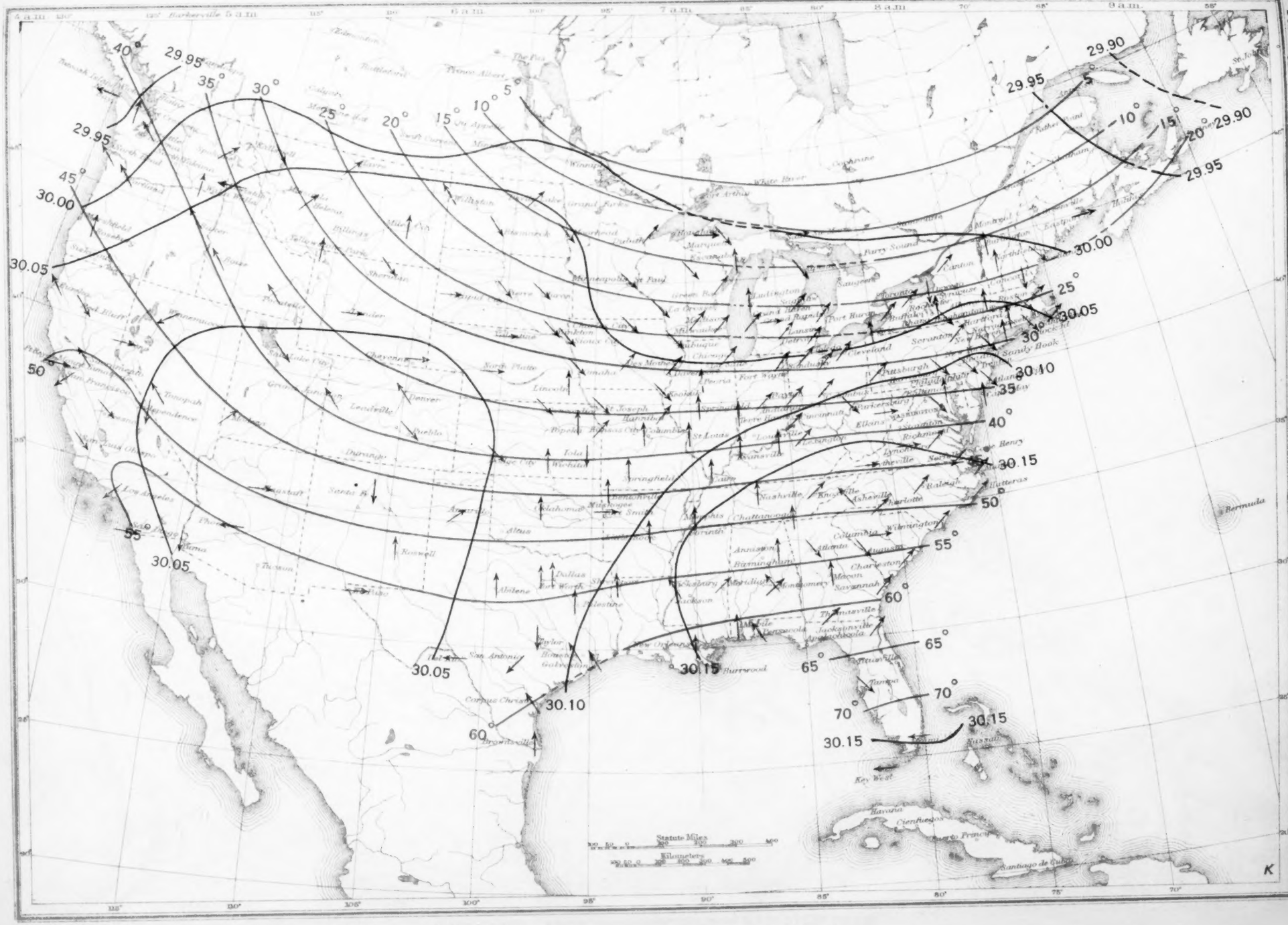


Chart VIII. Total Snowfall, Inches, February, 1918.

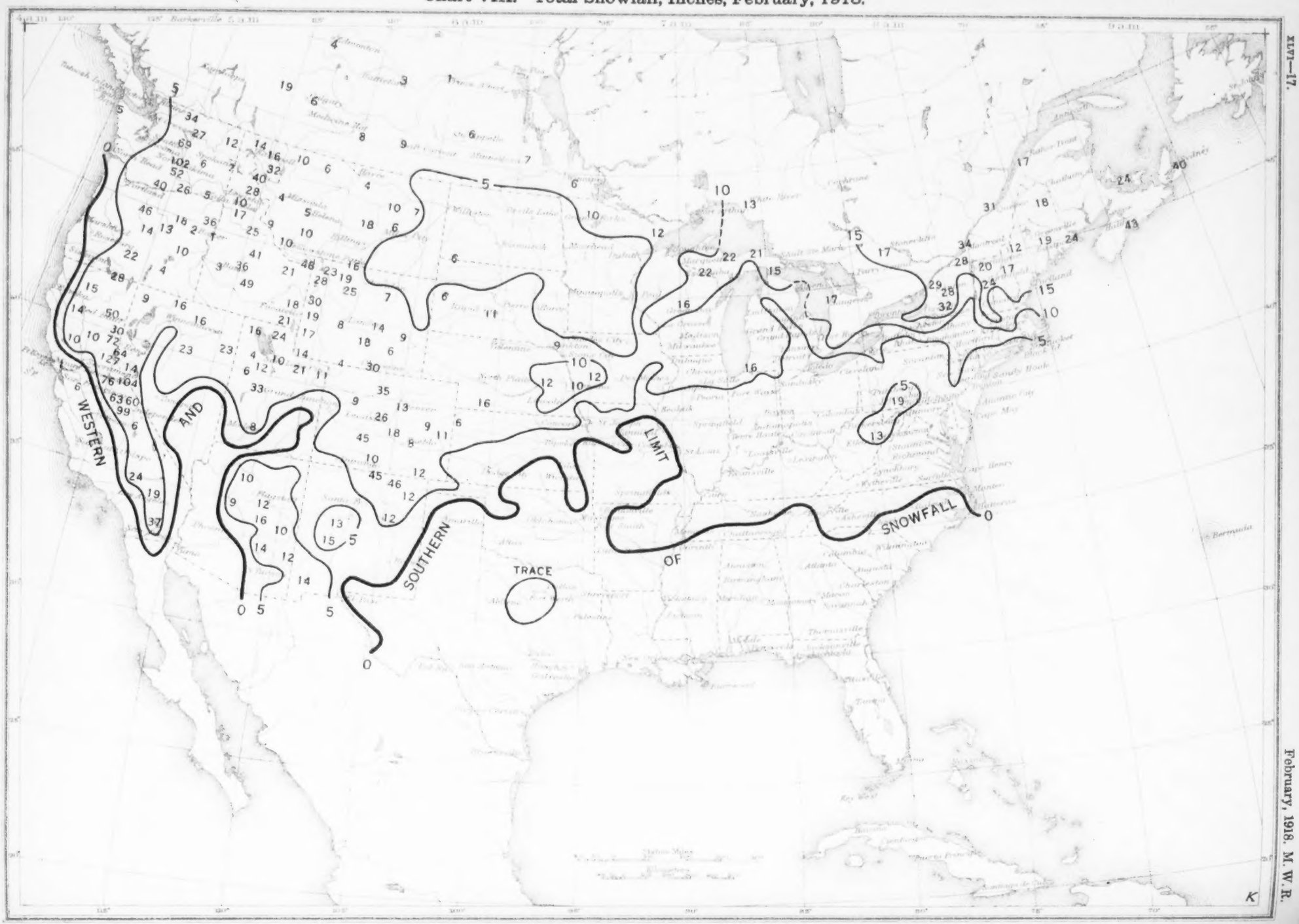


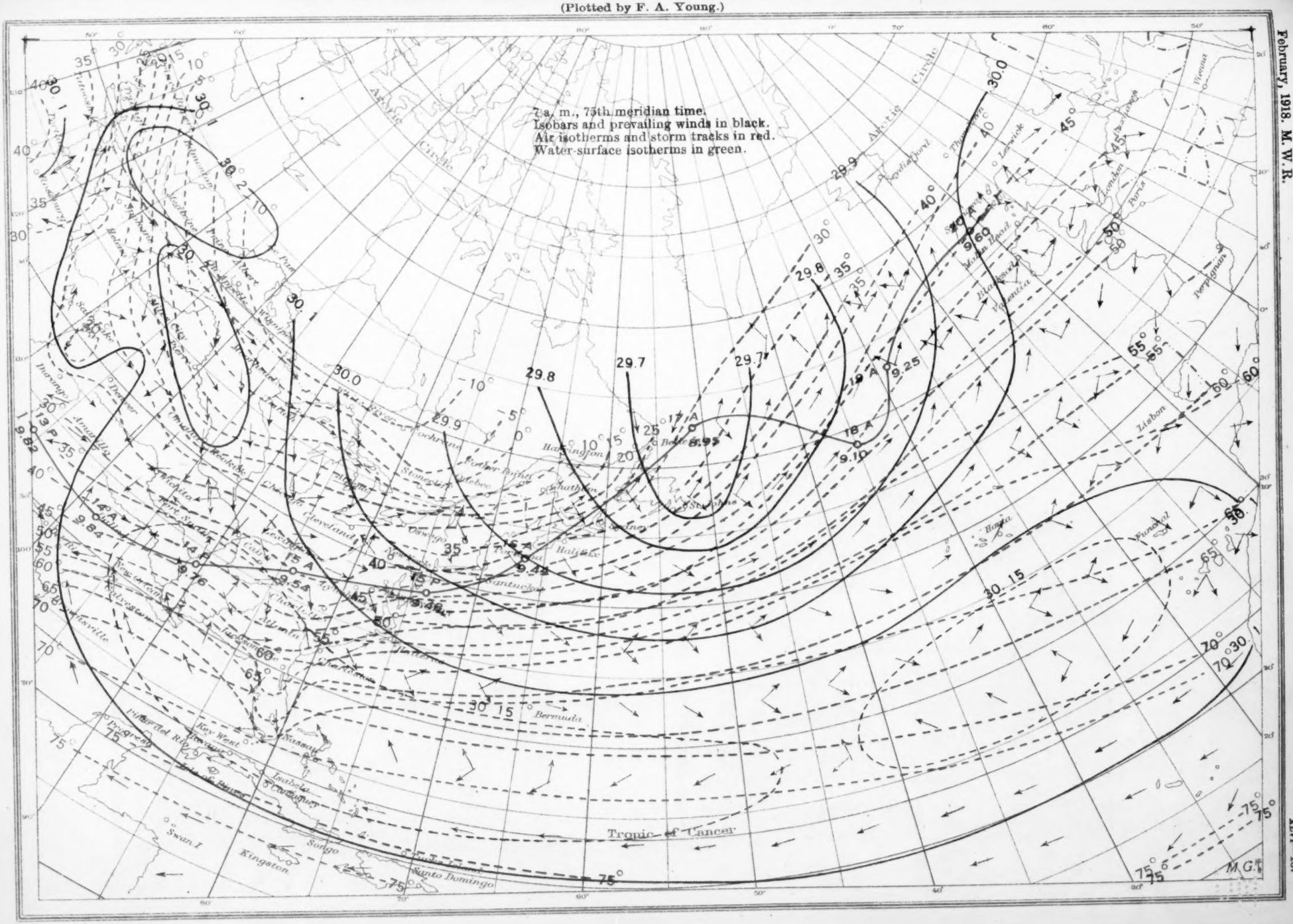





Chart IX. Means of Meteorological Data for North Atlantic Ocean, February, 1917.

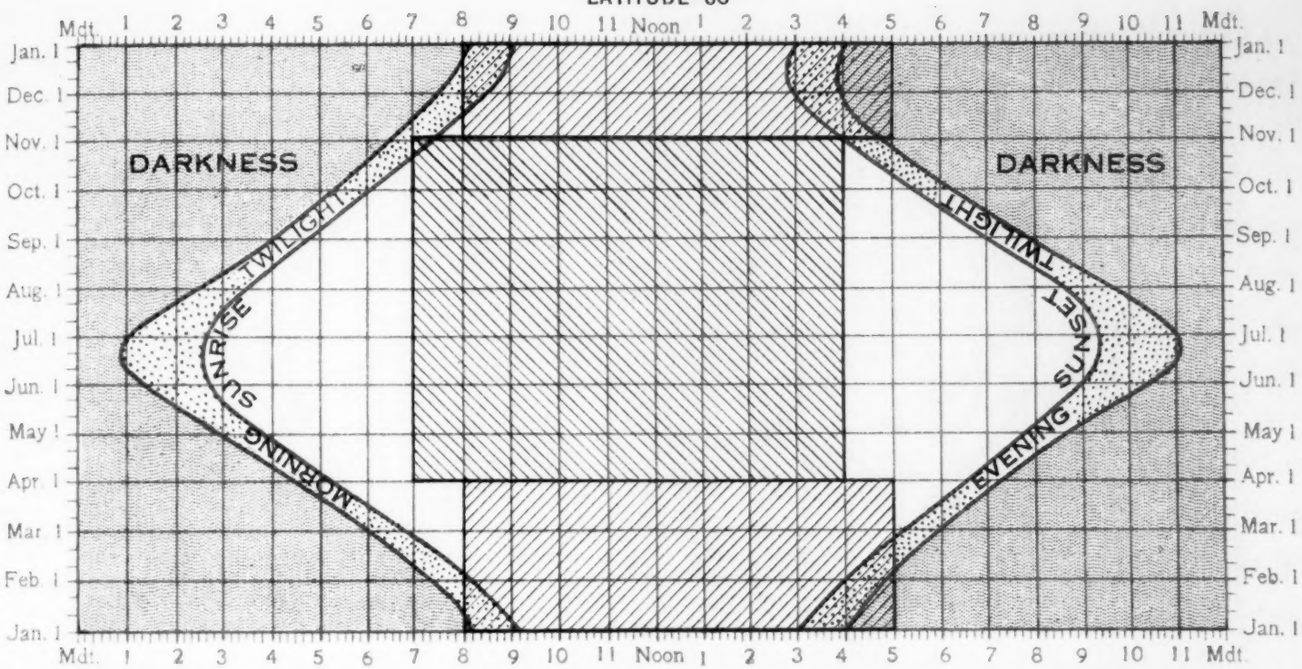
**Chart IX. Means of Meteorological Data for North Atlantic Ocean, February, 1917.**

(Plotted by F. A. Young.)



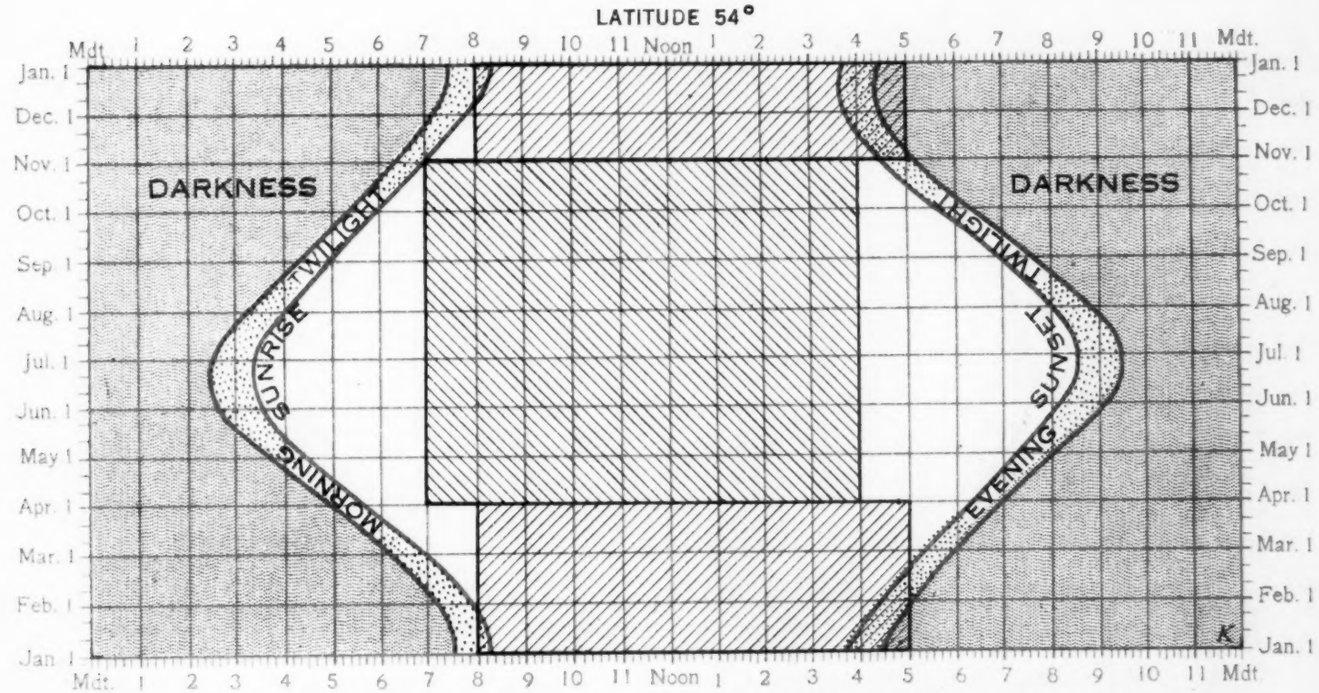
DAYLIGHT AND DARKNESS DIAGRAMS

LATITUDE 60°

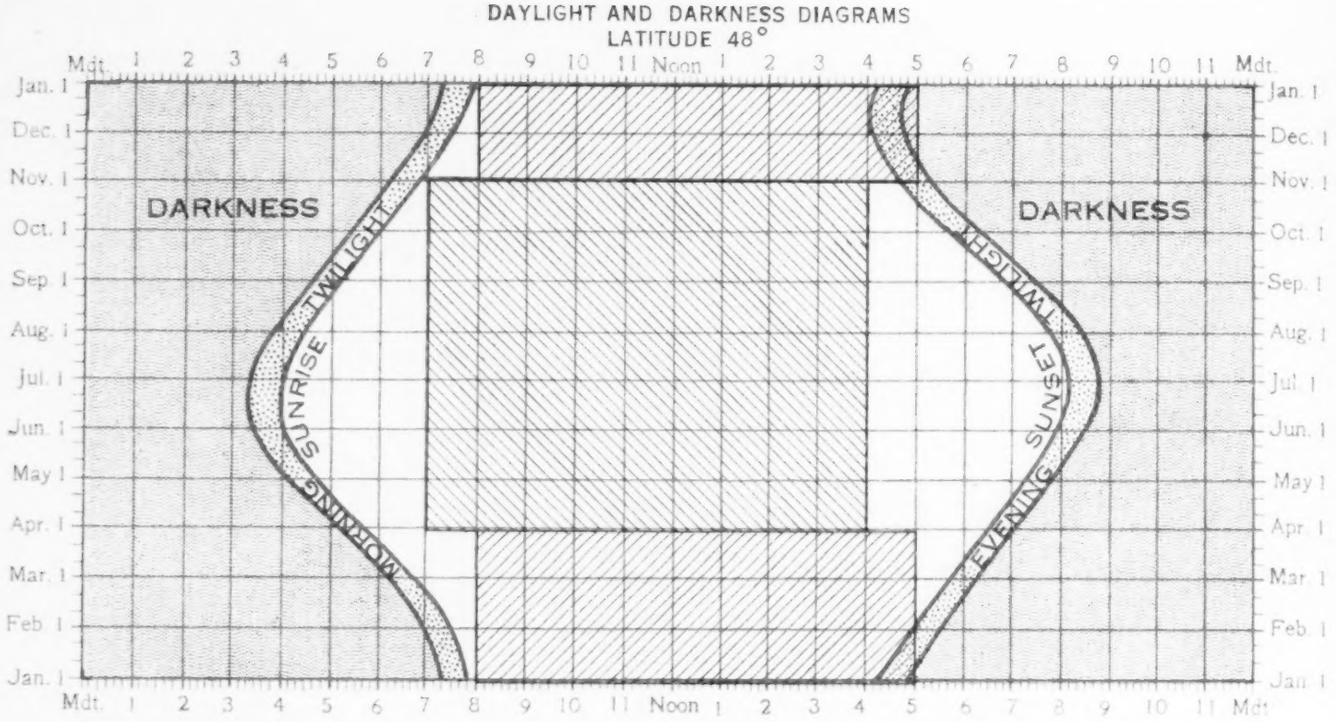



**American and European regions on parallel 60° N.: Southern Alaska, Hudson Bay; Cape Farewell, Shetlands, Kristiana, Petrograd.**

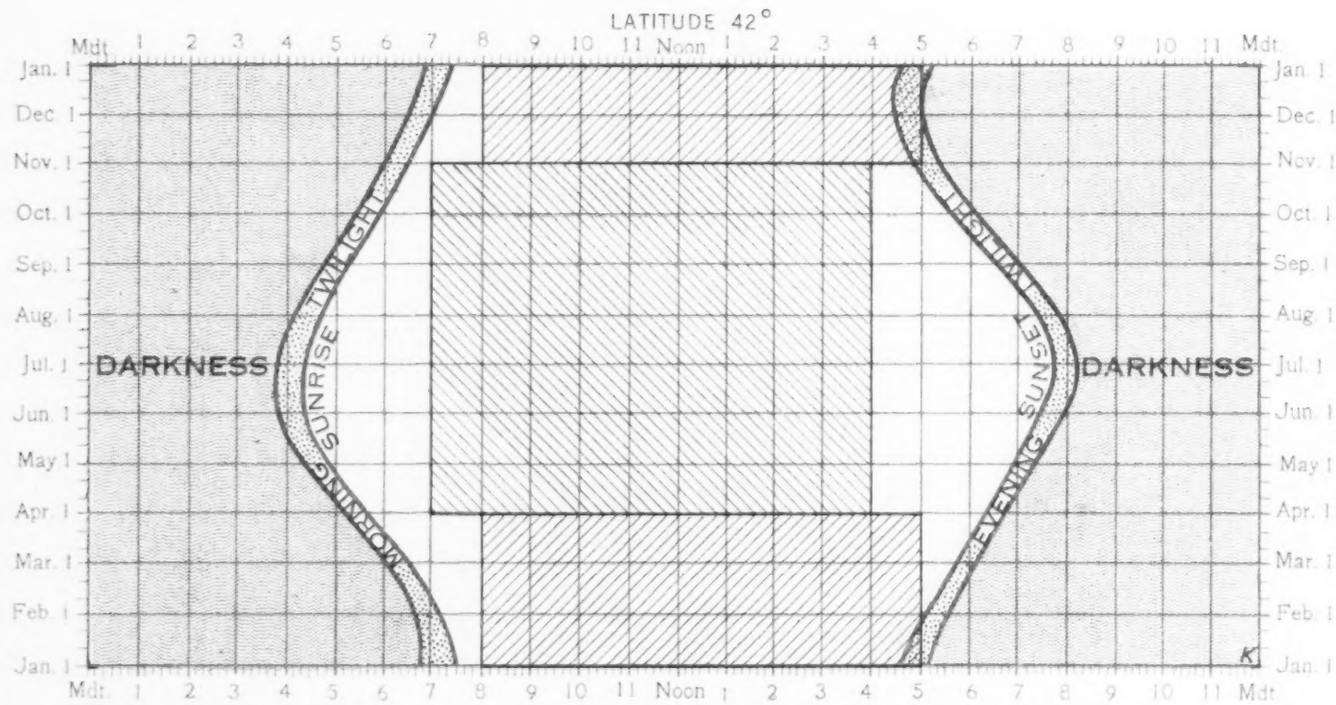
LATITUDE 54°




**American and European regions on parallel 54° N.: British Columbia to southern Hudson Bay, Labrador; British Isles, Denmark, Moscow, etc.**



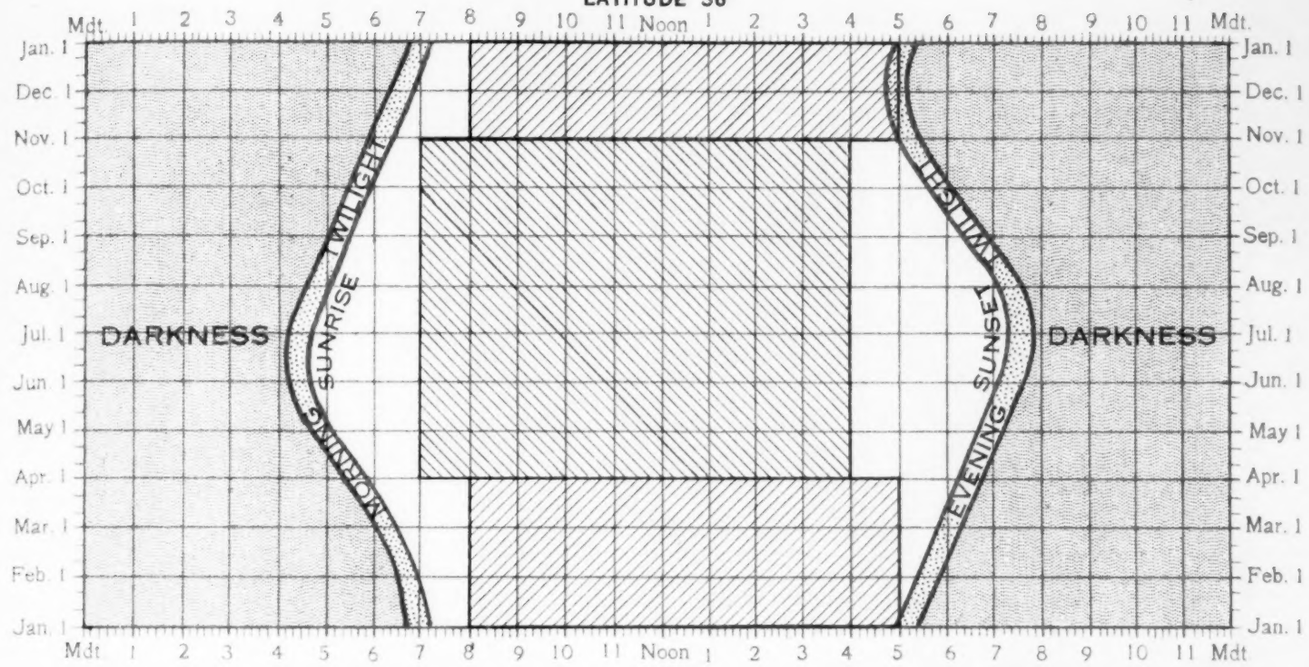

**American and European regions on parallel 48° N.: Northern boundary of the United States, Newfoundland; northern France, Bavaria, Austria-Hungary.**




**American and European regions on parallel 42° N.: Oregon, Nebraska, Lake Erie, Connecticut; southern France Italy, the Balkans.**

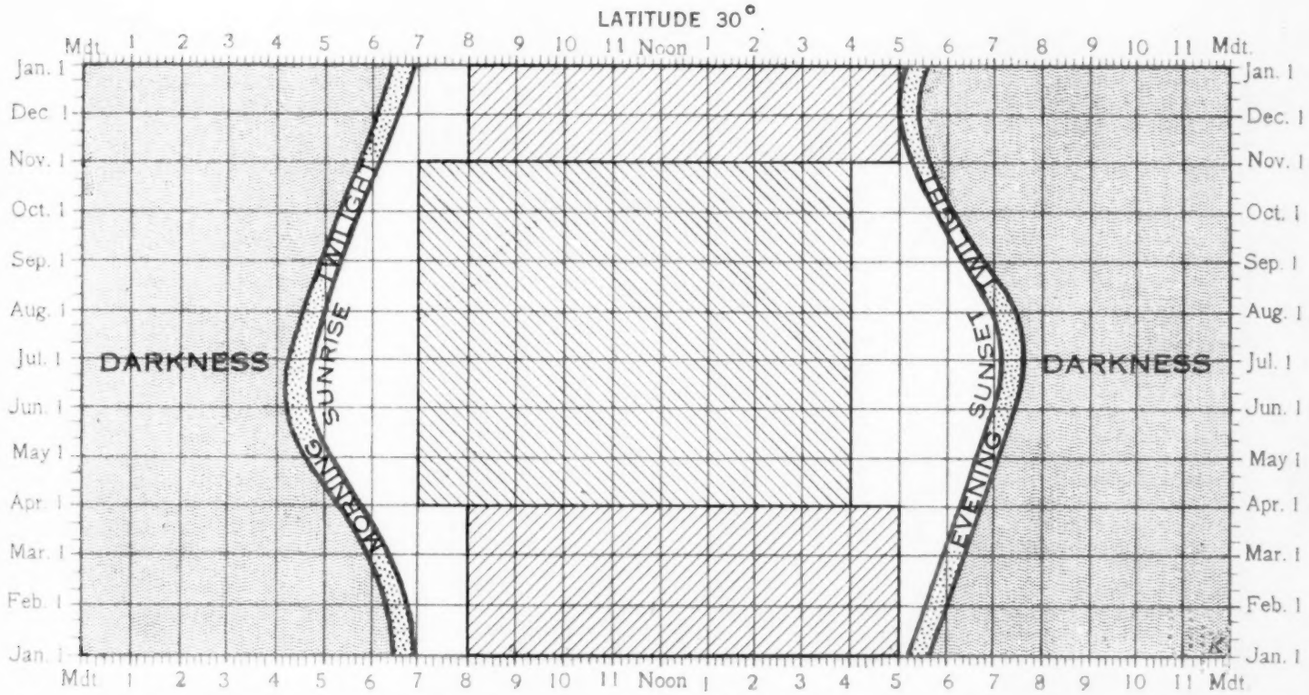
DAYLIGHT AND DARKNESS DIAGRAMS

LATITUDE 36°




**American and European regions on parallel 36° N.: California, Oklahoma, Tennessee, North Carolina; Azores, Spain, Greece, etc.**

LATITUDE 30°




**American and European regions on parallel 30° N.: Lower California, Southern Texas, Louisiana, Northern Florida; Madeira, Morocco, etc.**